PREPARED BY:
E.M. LUDWICK AND ASSOCIATES LTD.
WINNIPEG, MANITOBA

THE FUEL - SAVING POTENTIAL OF ROAD SPEED GOVERNORS ON COMMERCIAL TRUCKS

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MANITOBA/CANADA CONSERVATION AND RENEWABLE ENERGY DEMONSTRATION AGREEMENT

The availability of secure and affordable energy supplies is a subject of national concern. It is an accepted fact that our primary energy sources — oil and natural gas — are becoming less accessible and more costly. However, Canada is well-endowed with renewable and alternative resources that can provide a bridge into the future.

To this end, the governments of Manitoba and Canada entered into a Conservation and Renewable Energy Demonstration Agreement which was signed May 9, 1980 and terminated March 31, 1984. The Agreement was dedicated to the development and demonstration of conservation and renewable energy technologies. Equally cost-shared by the provincial and federal governments, the program had a total budget of $18-million.

The objectives of CREDA are:

- To develop and demonstrate promising new technologies, which, when widely adopted, will exploit renewable resources, conserve energy and/or use energy more efficiently.
- To develop broad public awareness of the potential of renewable energy and conservation technology.
- To provide opportunities for the commercial application of the technologies within Manitoba.
- To create economic spin-off benefits for manufacturing, industry and commerce.
- To create employment in new or existing energy-related industries.

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EXECUTIVE SUMMARY

This document is the final report for the road speed governor demonstration project sponsored by the Manitoba Trucking Association in co-operation with Manitoba Energy and Mines, and Energy, Mines and Resources Canada. Funding was provided by a Canada/Manitoba Conservation and Renewable Energy Demonstration Agreement (CREDA) contract and by a research and development contract from Energy, Mines and Resources Canada.

The original objective was to demonstrate the effect on fuel consumption of the application of road speed governors and anti-idling devices to commercial trucks. The term road speed governor is used to describe devices which alter driver behaviour by controlling highway speed mechanically and/or electronically. An anti-idling device reduces fuel consumption by shutting engines down instead of allowing them to idle during lengthy stops.

The project design consisted of an evaluation of alternative test devices, development of an experimental design for conducting tests, selection of motor carriers to participate in the demonstration, implementation of experimental procedures, conditions and data recording forms, analysis of daily fuel consumption before and after road speed governors were installed, statistical comparison of results and project documentation.

The intention was to conduct tests with four different motor carriers for each type of device to allow analysis of a range of operations. Due to difficulties with the recruitment and maintenance of project participants, the scope was narrowed. The anti-idling device tests were not conducted and only one carrier completed the road speed tests according to the original experimental design. However, the consultant was able to collect further data on road speed governor use from two other motor

carriers and this combination of carriers has allowed a useful analysis to be made of the effect of road speed governors on fuel consumption.

This report therefore covers the following:

- "before" and "after" fuel economy results of one motor carrier conducting tests as originally designed;
- intra-fleet comparisons of different types of trucks and governing systems currently in place with another motor carrier; and
- a two year annual fuel consumption analysis of a third company operating without road speed governors in one year and with road speed governors in the next year.

The results indicate that, within the study group, the use of road speed governors could reduce fuel consumption, but the magnitude of fuel saving was very user specific.

The potential benefits of RSG use are affected by the degree of conservation awareness throughout a company. Those carriers already practicing speed control through driver incentive or penalty and/or education programs and those who equip their vehicles for optimal fuel economy (radial tires, formula engines, deflectors, etc.) are likely to benefit less from the addition of an RSG.

There is some indication that the use of RSG could provide a cost effective way for a carrier achieving poor fuel economy to equalize with other carriers. The three carriers in this study achieved roughly equivalent average fuel economies of approximately 6 miles per gallon (47 litres per 100 kilometers) after governing their fleets despite different fuel economies prior to the test.

All carriers should consider using RSG's not only as a means to save fuel but also to reduce maintenance costs and to promote safer operation of their vehicles. Those carriers who are taking little or no action to reduce fuel consumption and are obtaining less than six miles per gallon (47 litres per 100 kilometers) could especially benefit from the use of these devices.

RÉSUMÉ ADMINISTRATIF

Ce document est le rapport final du projet de démonstration de limitateur de vitesse parrainé par la "Manitoba Trucking Association", Énergie et Mines Manitoba et Énergie, Mines et Ressources Canada. Ce projet a été financé selon les dispositions de l'Entente Canada-Manitoba de démonstration des énergies renouvelables et des économies d'énergie (DEREE) et en vertu d'un contrat de recherche et de développement établi par Énergie, Mines et Ressources Canada.

L'objectif initial du projet était de démontrer l'effet que les limitateurs de vitesse et les dispositifs coupe-moteur automatiques au ralenti pouvaient avoir sur la consommation de carburant par les camions de transport. Par limitateur de vitesse, on entend tout dispositif qui modifie le comportement des conducteurs en limitant, par un procédé mécanique ou électronique, la vitesse des véhicules sur les autoroutes. Par coupe-moteur automatique au ralenti on entend tout dispositif qui réduit la consommation de carburant en arrêtant le moteur au lieu de le laisser tourner au ralenti pendant de longues périodes.

Le plan du projet comprenait l'évaluation d'autres dispositifs d'essai, l'élaboration d'un programme expérimental pour la conduite des tests, la sélection des entreprises de camionnage devant participer aux essais, la détermination des conditions et méthodes expérimentales, la préparation de formules d'enregistrement des données, l'analyse de la consommation journalière du carburant avant et après l'installation de limitateurs de vitesse, la comparaison statistique des résultats et la documentation relative au projet.

Afin de tenir compte des divers modes d'exploitation, on s'était proposé au début de demander à quatre entreprises de camionnage de mettre chaque type de dispositif à l'essai, mais on dut réduire l'ampleur du projet par suite du manque de participants et des difficultés à les retenir. Les essais sur le dispositif coupe-moteur automatique au ralenti n'ont pas été effectués et une seule entreprise de camionnage a fait tous les essais avec les limitateurs de vitesse comme prévu initialement. Toutefois, grâce aux essais réalisés par

deux autres entreprises de camionnage, notre conseiller a pu obtenir des renseignements supplémentaires sur les limitateurs de vitesse et cela a permis de faire une analyse utile sur l'effet produit par ces dispositifs sur la consommation de carburant.

Les points suivants sont donc examinés dans ce rapport :

- les résultats de tests initiaux sur la consommation de carburant "avant" et "après" l'installation de régulateurs de vitesse sur les véhicules d'une entreprise de camionnage.

- une comparaison des résultats obtenus avec des camions et régulateurs variés appartenant à une autre entreprise de camionnage.

- les résultats d'une étude de deux ans sur la consommation de carburant effectuée chez une troisième entreprise de camionnage dont les camions ont fonctionné pendant la première année sans limitateurs de vitesse et pendant l'année suivante avec des limitateurs.

Les résultats fournis par le groupe d'étude indiquent que les limitateurs de vitesse permettent d'économiser le carburant mais que cette économie varie en fonction de l'usager.

Les avantages possibles du LV dépendent de l'esprit de conservation de l'énergie qui règne dans une entreprise. Les entreprises qui contrôlent déjà la vitesse de leurs véhicules au moyen d'encouragements ou de pénalités données à leurs conducteurs ou encore au moyen de programmes d'information et celles qui équipent leurs véhicules dans un but d'économie (Ex. : pneux radiaux, moteur de véhicule de course, déflecteurs aérodynamiques, etc.) bénéficieront sans doute moins des avantages offerts par les limitateurs de vitesse.

Il y a lieu de croire que les entreprises de camionnage qui utilisent trop de carburant pourraient efficacement réduire leur consommation et se trouver à égalité avec les autres en faisant installer des limitateurs de vitesse sur les moteurs de leurs véhicules. Grâce à l'emploi de limitateurs de vitesse les trois entreprises qui participèrent à cette étude réussirent à réduire la consommation de carburant de leurs véhicules à 6 milles au gallon (47 litres au 100 km), indépendamment de leur consommation antérieure.

Il y va de l'intérêt des entreprises de camionnage d'utiliser des LV, non seulement pour économiser du carburant, mais aussi pour réduire les frais d'entretien et promouvoir une plus grande sécurité de fonctionnement de leurs véhicules. Ces dispositifs pourraient profiter particulièrement aux entreprises de camionnage qui n'ont pris à peu près aucune mesure pour réduire leurs frais de carburant et dont les véhicules font en moyenne moins de 6 milles au gallon (47 litres au 100 km).

1. INTRODUCTION

In response to concerns about the high cost of fuels, their future availability, and the need to use fuels more efficiently, manufacturers have attempted to market a wide variety of devices promoted as having the capability of offering major fuel savings to truckers. Within the wide range of available fuel-saving devices, two types in particular appear to offer real value in terms of their fuel cost reduction potential for commercial truckers. These are road speed governors (RSG's) and delayed engine shutdown timers (or anti-idling devices).

A number of speed controls, cruise controls and governing devices have been used on vehicles for many years primarily for the purpose of restricting speed to legal limits. These devices have often been complex, unreliable and easily tampered with by drivers. For these reasons there has been a reluctance by trucking firms to use them and they have therefore not been widely used as fuel saving devices.

The purpose of this project was to demonstrate the effect on fuel consumption of the application of road speed governors and anti-idling devices to operators of commercial trucks. The Manitoba Trucking Association engaged E.M. LUDWICK & ASSOCIATES INC. to conduct tests in 1984-85. Funding was provided through the Canada/Manitoba Conservation and Renewable Energy Demonstration Agreement (CREDA) cost-shared by Energy, Mines and Resources Canada, and Manitoba Energy and Mines and a research and development contract with Energy, Mines and Resources Canada.

1.1 Project Objectives

The original objectives of the demonstration were to:

1. evaluate a variety of alternative road speed governors and anti-idling devices for inclusion in the tests;
2. design procedures for tests of road speed governors and anti-idling devices in order to yield statistically meaningful results;

3. select motor carriers able to control important test variables to participate in the tests;

4. implement testing programs with participating motor carriers, record data, and analyze results;

5. document the results of the evaluation of devices, testing procedures and results in a report;

6. create a broad industry and public awareness of the fuel saving - thus dollar saving - potential resulting from the use of speed controls and anti-idling devices by preparing promotional material and giving public presentations for the benefit of interested parties; and

7. communicate to the Manitoba trucking industry the benefits and costs of an anti-idling program or a speed control program based on the results achieved by participants in the demonstration program.

1.2 Scope of the Project

The project as reported herein was restricted to a determination of the fuel conservation potential of road speed governors. The original intention was to conduct tests on a broad cross-section of routes, operating conditions, types of equipment and fuels. Such tests would have allowed for comparison of results between companies, routes and other operating parameters. However, several problems were encountered which resulted in the need to alter the original method through which the fuel conservation potential of road speed governors was to have been demonstrated.

Nevertheless, it was possible to conduct tests as originally designed with Canadian Motorways. Furthermore, in the process of soliciting participation in this demonstration, it was learned that independent tests of the fuel economy achievable from the implementation of road speed governors had been run at Gardewine North and Canada Safeway and

that Gardewine North was about to begin its own test of the TRW Electronic Truck Engine Control.

The Project Steering Committee thus decided that a statistical analysis and documentation of the historical fuel consumption levels in these companies, supplemented by tests where possible, would demonstrate fuel economy levels that could be achieved by using road speed governors. For the purpose of this report, fuel economy is defined as fuel conserved in miles per gallon (or, litres per 100 kilometers).

It was not possible to meet the above objectives in regard to anti-idling devices because of the difficulty in recruiting the committed participation of trucking companies within the time period available for executing the demonstration. Motor carriers declined or withdrew participation from anti-idling device tests for several reasons including:

- fear of negative driver reaction toward shutting down engines on cold days;
- inability to restrict vehicles to operation within urban areas;
- need to idle vehicles to operate ancillary (e.g., power take off) equipment;
- a genuine belief that vehicles should be left idling since fuel wasted in this manner is trivial compared to associated driver discomfort; and,
- a lack of interest in participating in tests.

(Although tests of anti-idling devices were not carried out, preliminary research and suggested test procedures are presented in Appendix E.)

1.3 Scope of the Report

This document reports on the evaluation of alternative road speed governors for possible inclusion in tests, testing methodology used and

the results achieved with various types of road speed governors by Canadian Motorways, Gardewine North and Canada Safeway.

Canadian Motorways recorded before (without device) and after (with device) fuel economy of trucks equipped with Cummins OEM RSG's on their Winnipeg/Saskatoon run. Gardewine North provided historical statistical data on their governed fleet fuel economy, recorded fuel consumption and mileage data on selected vehicles for statistical comparison, and conducted tests of the TRW ETEC system. Canada Safeway Ltd. provided historical data showing improvement in fleet fuel economy achieved over a two year period as a result of implementing retrofit and OEM Cummins RSG's.

It is noted that road speed governors are mechanical devices employed not to alter the efficiency of engines or trucks but, rather, to alter the behavior of drivers. Consequently, the results of any such experiments can differ for any trucking company depending on current management policies and practices toward other fuel conservation devices (e.g. radial tires, wind deflectors, etc.), control systems (tachograph reading and enforcement) and general driver education and training. Nevertheless, the results of the research reported herein indicate that road speed governors represent a significant method for reducing fuel consumption by reducing speed.

1.4 Organization of the Report

This report is intended to be readily reviewable by motor carriers seeking information on the potential applicability of road speed governors to their respective fleets. Section 2 deals with the types of road speed governors that are available and focuses specifically on the Cummins Road Speed Governor and the TRW Electronic Truck Engine Control. Section 3 provides details on the test methodology (or experimental design) conducted and the selection of participants. Although modified somewhat in consideration of the circumstances mentioned in Section 1.2,

fleet managers can use the methodological principles to conduct their own tests. Section 4 documents the historical (in cases of Canada Safeway and Gardewine North) and experimental (in the cases of Gardewine North and Canadian Motorways) results the three companies achieved with road speed governors. The report concludes with a discussion of the economic benefits and future potential of road speed governors. Names of companies approached for participation in the demonstration project, technical details on road speed governors tested, detailed statistical data and test results are attached in appendices. A description of anti-idling devices to have been tested as well as suggested testing procedures and a bibliography of sources which a fleet manager may consult in order to conduct independent tests are also appended.

2. SELECTION OF ROAD SPEED GOVERNOR TEST DEVICES

The general term "road speed governor" can apply to any number of devices which work in different ways to alter driver behaviour by controlling highway speed mechanically and/or electronically. There are many devices designed to govern speed available on the market. Given the wide choice of devices and the project's budget constraints, it was necessary to conduct a pre-evaluation of the various devices available for testing. In the final analysis, those devices which in the opinion of the experimenters seemed the most appropriate were specified. Specifically, devices evaluated as being tamper-proof, simple to install, and which mechanically govern speed in the most fuel efficient gear(s) were chosen.

The selection of the devices used in the experiments is not to imply that there are not other road speed governors capable of performing in accordance with a given motor carrier's specifications. Devices were purchased off-the-shelf with no aim of promoting any particular product, but rather, for use in conducting objectively defined tests. That is, the purpose of these experiments was not to test or promote a manufacturer's make of road speed governor, but simply to determine and promote the principles and benefits (if any) of governing speed on commercial motor trucks. Because motor carriers operate under a wide variety of circumstances, companies wishing to save fuel by governing speed are advised to conduct their own independent tests of devices supplied and backed-up by reliable local suppliers.

2.1 Evaluation of Alternative Speed Control Devices

New, simple and relatively "driver proof" speed controls are available but they have not met with the acceptance they deserve due to the negative perceptions by the motor carrier industry of the earlier generation devices; such devices were easily tampered with by drivers and in some cases resulted in complete engine shutdown. New generation speed

controls have been reported as having the potential to reduce consumption by up to 15-25%* depending on the vehicle, task and driving habits.

Two types of speed control devices are adaptable to diesel engines - engine speed governors (ESG) and road speed governors (RSG). ESG's act to control speed by limiting engine RPMs. Because the concept of governing RPMs affects all gears, ESGs have met with strong driver resistance. The experience of Manitoba truckers consulted under the purview of this project has been that the low (e.g. 1,600) RPM engine (a dominant type of ESG) does not meet its objective of encouraging drivers to run their vehicles in the most fuel efficient gear.

Engine governor problems include:

a) engine governor "droop" - a built-in "inefficiency" which allows a tractor an extra three to six miles per hour at top road speed;

b) "throttle bounce" - road vibration transmitted through the driver's partially depressed right foot at top road speeds causing excessive fuel useage;

c) driver substitution of a high-speed fuel pump; and,

d) driver and/or mechanic tampering.

Yet another type of governor is generally known as the cruise control. While this device can offer some fuel savings if applied consistently, its use by the driver can be discretionary. In these circumstances, a device which allows the driver to set speeds at inefficient levels was

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* Source: John F. Weiss, Claude M. Ligon, Claude Travis and Henry Seiff, "An Analysis of Commercial Vehicle Speed Control Concepts," SAE Technical Paper Series II 821258, 1982 (See Appendix D).

considered counter-productive to the purposes of this experiment and may be viewed as a device that promotes driver comfort much more than fuel conservation.

Devices specifically known as road speed governors monitor and control actual road (as opposed to engine) speed usually only in the top gear. The only problems that are obvious in the use of the new road speed governors are the possibilities of driver tampering and incorrect installation. As a result, the ideal device should display certain characteristics:

1. It should be possible to set the device at the maximum speed desired by the trucking company rather than being subject to variable settings made at the discretion of the driver.

2. The device should be tamper resistant or have a system whereby tampering can be easily detected.

3. The device should not restrict the fuel pump or the engine in any way which impedes performance.

4. The device should have a simple hook-up procedure to reduce installation error.

5. The device should only limit vehicle speed in the most efficient gear or gears to reduce fuel consumption.

Following an initial evaluation of several devices available on the market, the Cummins Road Speed Governor and the Air Shield Road Speed Limiter were found to satisfy the requirements determined as being necessary to clearly demonstrate the benefits achievable through the use of an appropriate road speed governor on commercial trucks. However, as discussed in Section 2.4 (a) the Air Shield Device failed to operate in the manner specified and advertised.

2.2 The Cummins Road Speed Governor

The Cummins governor is an attractive speed control mechanism for truckers operating and retrofitting or purchasing Cummins equipped fleets. The Cummins RSG consists of an air control valve secured to the transmission which when activated by shifting the top speed mode adjusts the fuel pump setting accordingly. The principal manner in which driver tampering is discouraged is the disincentive of lengthy disconnection time as parts of the transmission must be disassembled to remove or restrict the device. The device is also sealed by the manufacturer to further discourage tampering.

Supplied by the Original Equipment Manufacturer (OEM, Cummins) the device costs approximately $640 installed ($1984 Canadian). However, if it is installed in the field on a retrofit basis, the time of installation is over eight hours and the cost is in the neighbourhood of $1,500 to $1,800 or less depending on the type of fuel pump. Further information on the Cummins road speed governor and the Cummins Big Cam III Formula Engine is provided in Appendix B.

2.3 The TRW Electronic Truck Engine Control (ETEC)

Perhaps the newest speed governing system available is the ETEC system which was designed to meet the following performance requirements:

- precise control of vehicle speed and engine speed
- maximum mileage at specified parameters
- elimination of the droop associated with conventional governing systems
- tamper-resistance

Unlike conventional governing systems, ETEC provides a combination of governing modes:

- road speed governing which limits maximum vehicle speed
- engine speed governing which limits maximum engine speed

- variable speed governing for vehicles equipped with power takeoff equipment
- top engine speed limiting which governs top engine speed through all of the gears to encourage the driver to use the highest practical gear
- cruise control, which enhances fuel savings and reduces driver fatigue

TRW literature claims that in two studies/tests of the ETEC systems, fuel savings of up to 12 percent have been achieved. Cost of the ETEC is approximately $2,600 installed. Further information on TRW's ETEC system is provided in Appendix C.

2.4 Other Mechanisms for Controlling Speed Evaluated But Not Tested

Other road speed governors were examined for testing in this demonstration project but were rejected or not selected because they did not fit the evaluation criteria.

a) Air Shield Road Speed Limiter

The Air Shield Road Speed Limiter was in fact selected for testing because of its operating characteristics, tamper resistance, adaptability to all types of engines and relative economy ($650 installed). The device basically consists of linkage actuator and a speed sensor. The actuator is installed into the throttle linkage and the sensor into the transmission. The system is air operated and electronically controlled. The absence of either air or electricity is supposed to cause immediate switching to a limited or fail-safe mode. (Should any attempt be made to tamper with the device, the unit is supposed to reduce speed to 45 mph until reset by the maintenance department.) Maximum speed, which is sensed from either transmission or tachograph, is set in accordance with the purchaser's wish and is then silicone sealed to further insure tamper resistance. However, when time came to install Air Shield's product on the CAT-equipped

trucks of Bulk Milk Haulers Ltd., it was found that Air Shield had removed the device from the market because of its failure to perform in the manner described above.

b) Webb Enterprises, Inc., Lenmar Industries, Hewitt Industries and Sturdy Controls

Road speed governors manufactured by these four companies feature electronic speed sensors. Control actuators meter the flow of fuel through pneumatic, hydraulic or electric valves. These devices involve alarms and engine shut-down if the driver exceeds the predetermined fuel-efficient speed. When this speed is exceeded, a caution light gives the driver two minutes to reduce speed before an alarm sounds in the cab; if speed is not reduced after 40 seconds, the engine shuts down and cannot be restarted until the vehicle is brought to a complete stop. Fear by motor carriers of negative driver reaction and possible road safety hazard were the reasons for which these types of devices were not selected.

c) Tachographs (Argo and Sangamo)

Widely used by many motor carriers, the tachograph produces a record (on circular cards) for each trip, of the time and speed at which a vehicle travels. Instances of idling, stopping and excessive speeding are readily observed. Tachographs can serve as a useful non-mechanical means for governing speed if trip cards are read assiduously and company speed policies are strictly enforced. However, tachographs were not selected for study in this demonstration because of the ease with which drivers can tamper with the device by bending the recording needle, or by using match sticks and/or rubber bands to conceal high speeding.

d) Electronic Trip Recorders (Rockwell Tripmaster)

Like the tachograph, the electronic trip recorder does not mechanically govern speed and was therefore not selected for

testing in these experiments. The Rockwell Tripmaster, for example, has an advantage over the tachographs in that it uses computer technology to provide digital readouts to drivers and stores information on speed, rpm's, idling, etc. which can be retrieved by management through a micro-computer at the end of the trip. The on-board computer will also sense and report if it has been tampered with. Again, the key to a trip recorder's success in controlling speed depends on dedicated reading of daily/trip printouts and enforcement of company road/engine speed and idling policies.

The Cummins road speed governor (OEM and retrofit) was identified as embodying most of the necessary characteristics and was selected for testing. This governor is in widespread use at Gardewine North and Canada Safeway. As well, the TRW Electronic Engine Control was also identified as an effective device embodying most of the above-mentioned characteristics.

3. EXPERIMENTAL DESIGN OF ROAD SPEED GOVERNOR TESTS

Generally speaking, the methodological guidelines followed in this project reflect Society of Automotive Engineers test procedures.* However, a special aspect of the current project required the use of somewhat unique analytical techniques that would not normally be necessary in straight SAE or laboratory-style tests where only a few observations are required. That is, road speed governors are not intended to alter the fuel efficiency or performance of an engine or vehicle; rather, they are mechanical devices aimed at altering the efficiency or performance of human beings (drivers). For this reason, it was hoped that a variety of motor carriers' operating circumstances could be examined in the belief that differing management techniques, driver attitudes, etc. would reveal themselves in the form of fuel savings, through statistical analysis and inference of before (without devices) and after (with devices) test data.

Although such analyses and comparisons were not possible, this section discusses the originally designed methodology which can be used by motor carriers wishing to carry out their own tests.

3.1 Test Methodology

The statistical design of the experiment was subjected to refinement and elaboration to reflect comments and suggestions made by representatives of Energy, Mines and Resources Canada, Manitoba Energy and Mines, Manitoba Highways and Transportation, and the Manitoba Trucking Association. Importantly, all truckers participating in the project (and others not participating) were consulted extensively in order to seek their advice about the design components of a statistically sound and operationally practical test of road speed governors.

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* Society of Automotive Engineers, Joint TMC/SAE Fuel Consumption Test Procedures - Type II, SAE J1321, Oct. 81, reprint, 22 pages.

Following the evaluation of a variety of potentially testable devices, several important factors were taken into consideration in developing the statistical methodology including:

1. definition of testable route segments and run frequencies (driving cycles and replications);

2. identification of test procedures and operating conditions to be followed during the tests (e.g. maintenance policies, driver and vehicle deployment, etc.);

3. specification of a cross-section of operating test conditions including road conditions and types of traffic/goods carried;

4. specification of a cross-section of available test materials including different types of power units and trailers/bodies to be used in order to broaden the widespread adaptability of results; and,

5. determination of data recording (e.g. fuel consumption measurement) systems which minimize interference with drivers' regular responsibilities but which provide the maximum appropriate level of information.

3.1.1 General Statistical Considerations

A wide variety of techniques have been used by automotive engineers, statisticians and other practicioners to determine the fuel economy of a wide array of vehicle alterations. Each of these methods has its own merits appropriate to the circumstances under which the tests are to be conducted. (See Appendix D for a bibliography of testing procedures.)

A frequently used technique for measuring changes in fuel economy is to examine the differences in before and after fuel economy on a vehicle or fleet and to conduct "t-tests" on the statistical significance of the main difference. Alternatively, an examination may be made of fleet fuel economy differences between two "identical fleets", one equipped with devices and the other not.

This type of test is usually restricted to testing the simple statistical premise or hypothesis that there is no difference between the fuel economy of a governed fleet and an ungoverned fleet.

It is doubtful whether any two fleets are really similar enough in all respects to satisfy the statistical assumptions of the above type of test. Therefore, the carriers approached to participate in the early stages of this project concurred with the suggestion that the tests should be conducted on a before/ after basis comparing a vehicle's own performance with and without a device. This proposition is based on the widely held premise among senior fleet managers that over a period of a few months (even up to a year), a vehicle's operating characteristics and performance scarcely change. Participants further agreed that significant variation may be found in test results between routes, between driver types (one-man vs. slipseat), among routes within carriers, among driver types within carriers, etc.

The program of statistical analysis was therefore designed in order to seek not only differences in fuel economy, but to attempt to explain through inference the causes or sources of variation based on the statistical premise that there is no difference in a truck's fuel economy before and after it is governed.

3.1.2 Design Parameters

An important design consideration is the number of observations (or replications) of cycles (or route segment runs) required to provide statistically significant results. Several carriers were asked to select at random trucks of a type representative of their fleets and to provide fuel economy (miles per gallon) data over the past year. This data served as a means for determining the variability in fuel economy allowing in turn for the derivation of the minimum number of cycle runs which would have to be measured.

In order to determine the number of cycles required for the experimental results to be statistically significant, the objective was set that the

demonstration project will have been considered to have yielded satisfactory results if the fuel economy measurements (in miles per gallon or litres per 100 kilometres) were accurate to within 5% of their true value (e.g. mean = 5 mpg ± 0.25 mpg, 55 litres per 100 kilometres ± 11 l/100 km) 95% of the time. Within these parameters and in consideration of the historical fuel economy data provided by the carriers, the range of cycle observations required was determined to be between eight (for one carrier) and 20 (for another). (This upper end is considered high due to that particular carrier's deployment of vehicles in multiple uses.) It was thus determined that 30 would be a "safe" number of cycle measurements.

For any given carrier participating in this project, an RSG test cycle was defined as a route segment over which load, equipment and driver do not change.

The observation of 30 "base" cycles before installation of the device and 30 "test" cycles after installation of RSG's could take anywhere from two to six weeks to complete depending on the particular carrier's frequency on a particular route. (Wherever possible, high density routes were to have been purposely selected to maximize data collected over a minimum period of time.)

3.1.3 Test Procedures and Operating Conditions

It was recognized that because of different management styles, driver attitudes, and current levels of commitment to fuel conservation, measuring the normally appropriate number of base and test cycles might still result in inconclusive tests for some carriers. Alternatively, it is also possible to draw erroneous conclusions from test data - for example, was a company's fuel economy using an RSG improved due to a change in driver behavior, a high quality test device, a better truck or engine, etc.?

Research was undertaken to determine the relative importance of several effects which could lead to confusing results which should be controlled or accounted for through correction factors. On the basis of this research, a number of important factors were identified and participating carriers agreed that the following items should be controlled:

a) Fleet Representativeness of Tests: Test routes, cargo weights, and equipment type and age chosen were to be representative of actual operations and fleet conditions;

b) Equipment Misdeployment or Modification: Power units and trailers/bodies tested were not to be used for other purposes or on other routes or to be modified in any way until the series of before and after tests were completed;

c) Long Haul Idling: Drivers were to be instructed not to unnecessarily idle trucks and to keep driving within urban areas to the minimum possible;

d) Recommended Vehicle Operation: To the extent controllable by the company, vehicles were to be operated according to vehicle, engine and transmission manufacturers' recommendations (engine speed and shift points);

e) Mechanical Condition and Maintenance: All vehicles were to be in proper operating condition, as determined by the operator conducting the test, at all times. All pairs of test vehicles were also to be in similar mechanical condition and representative of the condition of vehicles in each company's fleet. All test vehicles were to undergo the operator's regular maintenance program whenever necessary at approximately the same time for all test and non-test vehicles operating in similar circumstances;

f) Driver Skills: Drivers selected were to be sufficiently skilled so that the test results would not be affected by improvement in the driver's technique during the test period; and,

g) Instrumentation: Speedometers and odometers were to be checked for accuracy and calibrated (where necessary) before the series of tests were run.

In addition to signing agreements to control the above-mentioned factors, participating companies provided complete documentation of the relevant characteristics of each test vehicle (power unit and trailer/body) to assist in the explanation of anomalous variation, if any, due to mechanical considerations. Experimental procedures and conditions and examples of the vehicle specification sheets are provided in Appendix F.

3.1.4 Data Recording Systems

Another source of potentially confounding information lies in the nature, amount and quality of data collected. As discussed in the previous subsection, controlling the procedures followed serves to reduce the possibility of erroneous data arising from "casual" experimental conditions. Further, the use of fuel flow meters, properly calibrated instruments, analysis of tachograph card readings and other measures all help to reinforce data quality. In this regard, the Diesel-Comp Fuel Economy Meter was selected among several choices as being able to most economically and accurately record fuel consumed. However, deficiencies were discovered in these fuel flow meters which could not be corrected within this project's completion deadlines. It was nevertheless possible to obtain statistically satisfactory fuel consumption data from daily fuel pump readings.

To ensure that data collected at the end of each cycle run was sound and accurate, the following steps were undertaken:

a) company/device test/run-specific data collection sheets (printed pads), to be completed at the beginning and end of each before and after cycle (whether daily or longer) were prepared;

b) readings were provided by the carriers whenever requested by the consultant;

c) daily observations were reviewed to ensure consistency;

d) the consultant met with each carrier as frequently as required to explain any aberrations in data, to ensure that test procedures and conditions were being followed, and to collect completed data forms.

The data gathered included date, trip number, origin/destination, miles, gallons (or litres), and driver name.

3.1.5 Correction of Fuel Consumption Data for Atmospheric Conditions

Another type of control was used to help ensure the statistical validity of the experiment. That is, the development of correction factors for the effect of temperature on rolling resistance and atmospheric effects on fuel consumption. It was assumed that seasonal changes in the energy content of fuel did not affect the experiment because all tests were run using "winter fuel". Arrangements were made with Environment Canada to supply daily weather reports for the duration of the experiments for those areas included in the carriers' test region.

The correction formula used is the SAE recommended practice documented in "Fuel Economy Measurement-Road Test Procedure SAE J1082" and is of the form:

Correction Formula (U.S. units of measure)

Corrected mpg = observed mpg x T_sCF X P_bCF X T_fCF X HVCF

where:

T_sCF = average ambient temperature during test cycle correction factor, °F

P_bCF = average barometric pressure during test cycle correction factor, in. Hg

T_fCF = average fuel temperature at measuring instrument during test cycle correction factor, °F

HVCF = heating value of test fuel correction factor

Correction Factors (U.S. units of measure)

$T_sCF = 1.0 + 0.0014\ (60 - T_s)$

$P_bCF = 1.0 + 0.0084\ (P_b - 29.00)$ for interstate cycle (55 mph)

$$T_fCF = \frac{1}{\text{multiplier for volume reduction to 60°F from the tables}}$$

$$HVCF = \frac{K}{\text{volumetric net heating value of test fuel (in BTU, where)}}$$

K = 126,700 for ASTM 1D type fuels
= 129,900 for ASTM 2D type fuels

NOTE: Volumetric net heating value of the test fuel is obtained by using the observed API gravity at 60°F and the 50% distillation point.

In addition to the above correction factors, the experimenters determined that a further correction factor was required to account for cold Canadian winter conditions related to the effect of temperature on vehicle rolling resistance. Thus an empirically derived multiplier between 1.0 and 1.1 for observed ambient temperatures between 0°C and -30°C was developed by the study team's mechanical engineer (a member of the S.A.E.).

3.1.6 Actual Test Procedures

Where it was possible to conduct tests, the above procedures were followed as closely as possible. In particular before and after (i.e., with and without road speed governors) data were recorded at Canadian Motorways following the above-mentioned procedures. In the case of Gardewine, observations "with" and "without" certain devices using otherwise similar procedures were recorded. In both cases, daily weather observations were also recorded in order to apply the correction factors described in section 3.1.6. Canada Safeway's tests were conducted independently and their results are reported on the basis of changes in annual fuel economy over a period of two years.

3.2 Selection of Road Speed Governor Test Participants

In the developmental stages of this project it was considered that the success of the test depended on fleet managers' technical knowledge of and commitment to energy conservation. The presence within motor carriers' operations of frequently repetitive hauls or driving cycles was considered important. Consultation with the Manitoba Trucking Association and the Manitoba Department of Highways and Transportation resulted in the identification of four companies considered as being best able to meet these requirements.

In the time that elapsed between the Manitoba Trucking Association's request for funding and Manitoba/Canada approval, important changes in traffic, operations, personnel and attitudes within these four companies caused most of them to withdraw participation. When most of these firms withdrew, concerted efforts were made to recruit new participants. These in turn declined participation or withdrew for several reasons including:

1. Implementation of strict enforcement of company speed policies through tachograph card readings removed the need to introduce governors.

2. Increasing moves toward hiring independent contractors or lease operators removed the desire or ability of a number of firms to control speed. (Independent contractors are paid on a per mile basis and it is their own responsibility to control fuel costs.)

3. In two cases, the initial persons who had agreed to conduct tests on their companies' behalf had resigned their positions; their successors had no desire or interest in participating.

4. Some companies independently implemented their own road speed control programs choosing either to specify OEM Cummins governors in newly purchased equipment, or installing electronic trip recording devices.

5. Traffic in the preselected lanes on which tests were to be conducted had declined to a point where test vehicles could no longer be dedicated to single repetitive origin/destination pairs.

6. Many firms approached were not able to meet the required experimental rigour because of:
   - irregular routes
   - infrequent runs
   - lack of control of vehicle deployment (e.g. dispatching done by contract lessee).

7. Still others declined participation because of:
   - general disinterest
   - lack of managerial time to properly organize and control experiments
   - fear of driver aggravation
   - fear of union demand for higher wages for drivers conducting tests.

Furthermore, it was not possible to secure the participation of new recruits within the project's completion deadlines.

In addition, completion of tests was hampered in two cases due to the need to remove and repair the Diesel-Comp fuel consumption recording devices, and in another case where the Air Shield Road Speed Limiter was removed from the market just prior to the time it was to have been tested.

Despite these difficulties it was possible to document three companies' experiences with road speed governors. Canadian Motorways agreed to conduct tests of Cummins OEM governors using methodological procedures discussed in Section 3.1 of this report. Gardewine North's fleet has been equipped with Cummins OEM governors for three years; this firm agreed to share historical data and to conduct tests of the TRW ETEC system using a somewhat modified methodology. Canada Safeway, who had already conducted their own tests before the demonstration project began, agreed to share their results.

3.2.1 Canadian Motorways Ltd.

Canadian Motorways is a major inter-city motor carrier with operations from Montreal to Vancouver and Whitehorse and terminals in several major American centres. The company operates a fleet of nearly 500 tractors, 135 straight trucks and over 1500 trailers. The company has been conscious of fuel costs for many years. For example, in 1974 at a time when energy conservation was not yet of much concern they conducted an independent 3 month test on four highway units pulling single trailers. At 20,000 miles (32,187 km) of base runs, wind deflectors, radial tires and thermatic clutch fans on formula engines were installed. After running the equipment for another 20,000 miles (32,187 km), the company determined it could achieve the following savings:

- wind deflectors	8%
- radial tires on tractor axles	6%
- thermatic clutch fan combined with formula engine	14%
Total tested savings	28%

Prior to running these tests and introducing the modifications to their fleet, Canadian Motorways' average fleet fuel economy was approximately four miles per gallon (summer). Today this has risen to 6.25 miles per gallon (45 litres per hundred km) at a time when much larger loads (in double and triple trailers) are being hauled. Most of these savings have resulted from the implementation of the above-mentioned items and improved formula engines. Today, Motorways is looking to road speed governors to improve its fuel efficiency further.

3.2.2 Gardewine North

Gardewine North is one of the largest intra-provincial motor carriers in Manitoba. In addition to its fleet of 35 tractors operating between Winnipeg and Northern Manitoba the company operates an additional 45 units under contract to several lease customers across the prairies. Tractors are predominantly Ford (90%) equipped with Cummins engines (80%) and Fuller transmissions. The company's fuel conservation efforts began

in earnest in 1977-80 with tests of radial tires. The results led the company to retrofit some 185 pieces of equipment to radial tires over a three year period.

In 1980, Gardewine took delivery of 25 Cummins Big Cam I Formula low RPM engines which helped reduce the firm's fleet average fuel consumption. The addition of 30 Big Cam II Cummins formula engines in 1981 yielded further savings. In 1982 the introduction of 25 aerodynamically designed Ford LTL's equipped with Cummins Big Cam III Formula RPM-reduced engines with road speed governors provided yet additional fleet savings. The pre-1979 fleet average fuel economy of 4.9 miles per gallon (70.6 litres per 100 km) was improved to approximately 6 mpg (47 litres per 100 km) by 1983. Today the company is looking for further fuel savings through a new product called Electronic Truck Engine Control (ETEC) manufactured by TRW.

3.2.3 Canada Safeway Ltd.

Canada Safeway Ltd.'s Winnipeg-based trucking operation is responsible for the distribution of goods from central facilities in Winnipeg to over 75 grocery stores in Manitoba, Saskatchewan and Northwestern Ontario. The fleet consists of 20 highway units, half of which are Fords and the remainder a combination of Freightliners and Western Stars. The average age of the equipment is 6 to 7 years. All trucks are equipped with Cummins 300 "Big Cam" engines and Fuller transmissions. Single boxes (plain and temperature-controlled) varying in length from 40' to 46 1/2' (12.2 to 14.2 meters) are the mainstay of the trailer fleet.

Having achieved significant fuel savings (reported in Section 4.3) with road speed governors which have gradually gained driver acceptance in the company, Safeway's local fleet manager is mindful of new technological developments which will enhance fuel economy. For example, although speed is now governed at 55 miles per hour (90 kmh) and 16-1700 RPM in the top gear, drivers are still capable of eliminating fuel savings by revving the engine up to 2300 RPM in the lower gears. In this regard the

company has initiated a program of installing Rockwell Tripmasters (1984 cost of $2,000) which provide detailed trip reports documenting idle time, departure and arrival time, hours stopped, length of time at speeds over 55 mph (90 kmh) and RPM's over 1700 and fuel economy. Given a firmly enforced company policy of reviewing the trip reports and correcting excessive revving by individual drivers, Canada Safeway expects to achieve further additional fuel savings.

4. DEMONSTRATION RESULTS

4.1 Canadian Motorways Ltd.

Canadian Motorways agreed to participate in the CREDA/MTA sponsored road speed governor demonstration project between October 1984 and March 1985. "Before" and "after" data (i.e., with and without Cummins OEM Road speed governors) were recorded on two highway units operating on scheduled hauls between Winnipeg and Saskatoon. Both units were 1984 model Ford LT 9000's equipped with Fuller transmissions and Cummins Bio Cam III Formula 350 engines with built-in (OEM) road speed governors. (More details on Motorways' test equipment are provided in Appendix F). The governor was left unactivated for 30 before or base cycles, then set at 55 mpg (90 kmh) for 30 after or test cycles. Because of difficulties with the Diesel-Comp fuel consumption recording device, daily fuel consumption data was taken from fuel pump readings.

The test results are as follows:

Observed Average Fuel Economy in Miles per Gallon
(litres per 100 kilometers)

	Before	After	% Change	Statistical Significance*
Test Unit #1	5.76 (49.0)	5.84 (48.4)	1.4 (-1.2)	74% confidence
Test Unit #2	5.61 (50.3)	5.59 (50.5)	-0.4 (0.4)	48% "
Units #1 & #2 combined	5.68 (49.7)	5.69 (49.6)	0.2 (-0.2)	54% "

Fuel Economy Corrected for Atmospheric Conditions
Miles per Gallon (litres/100 km)

	Before	After	% Change	Statistical Significance
Test Unit #1	6.09 (46.4)	6.04 (46.8)	-0.8 (0.8)	65% confidence
Test Unit #2	5.68 (49.7)	5.87 (48.1)	3.3 (-3.2)	89% "
Units #1 & #2 combined	5.88 (48.0)	5.94 (47.5)	1.0 (-1.0)	70% "

* Confidence levels less than 90% are usually not considered relevant by statisticians.

The observed average fuel economy shown in the first half of the above table is based on actual fuel consumed and distance travelled daily. However, data was recorded over a period of several months (in the cases of Canadian Motorways and Gardewine North) and was subject to widely fluctuating daily weather conditions. Therefore, fuel economy corrected for atmospheric conditions (in all cases in this report) shown in the second half of the above table, for example, provides the more reliable indicator of true fuel economy.

Among the above results only one of the test units shows an improvement in fuel economy approaching normally accepted statistical confidence levels. That is, fuel economy on test unit #2 improved by 3.3% and at the 89% confidence level. Test unit #1 showed an insignificant decline in fuel economy. It is noteworthy that test unit #1 achieved a fuel economy of over 6 miles per gallon (47 litres/100 km) before and after the governors were set at 55 mph (90 kmh). These results are a combined reflection of radial tires, wind deflectors, formula engines and experienced drivers. In other words the unit has been equipped and operated in a manner which means that fuel economy would not be improved with the installation of a road speed governor. On the other hand test unit #2 equipped identically to test unit #1 was not achieving as good fuel economy and the addition of a road speed governor brought fuel economy more in line with that of test unit #1.

4.2 Gardewine North

Gardewine has been using Cummins OEM road speed governors for several years. The firm agreed to participate in this demonstration project by sharing historical data which allowed for the development of an averaging of the governed fleet's fuel economy. Data from February 1984 to March 1985 for all trucks with governors were used to demonstrate fuel economy levels achievable by governed fleets. Furthermore, daily fuel economy data were recorded to provide a statistical comparison of the monthly fuel economy of the CAT-equipped versus Cummins-equipped vehicles. Similar comparisons were made between Cummins equipped line haul and heavy (ore) haul vehicles.

Finally, a special test of the TRW ETEC System on the company's 88 mile Spruce Point/Flin Flon operation was conducted to compare the fuel economy of a truck equipped with the ETEC system versus a truck equipped with no governing system. (The trucks hauled identical loads in identical equipment (except for governing systems) under identical road and weather conditions.) Again, the fuel economy of those two vehicles was recorded daily (or sooner depending on when fuel was taken) on special forms in the manner discussed in Section 3 of this report.

4.2.1 Overall Fuel Economy of the Gardewine North Fleet

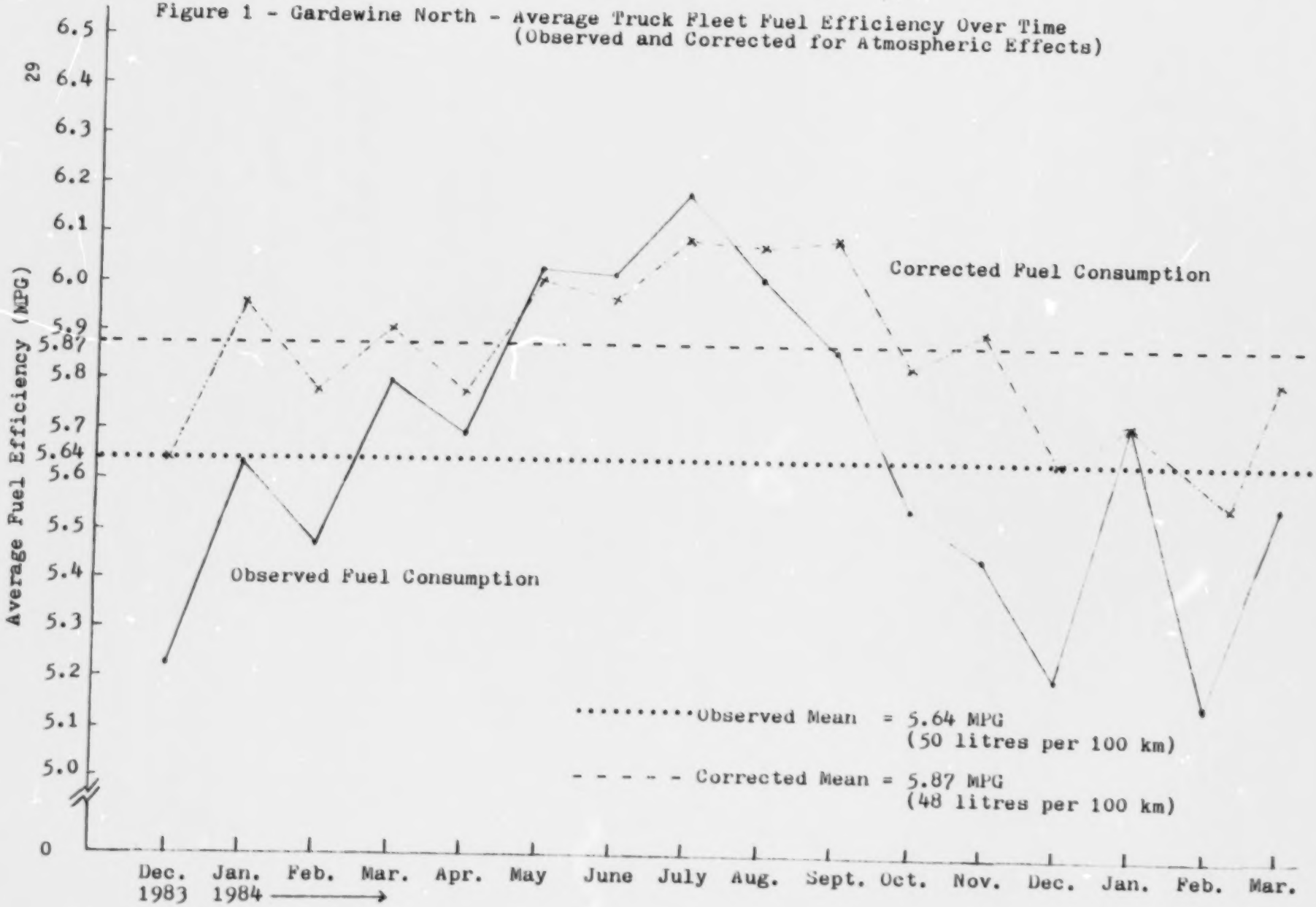
Figure 1 plots the monthly average fuel economy of Gardewine's intra-provincial fleet. Some 35 speed governed units operate between Winnipeg and several points in Northern Manitoba. Average observed fuel economy over the course of a year is 5.64 mpg (50 litres/100km) rising to 6.2 mpg (45.5 litres/100 km) in summer months and declining to 5.2 mpg (54.3 litres/100 km) in winter months. Using the procedure described in Section 3.1.5 of this report for correcting fuel consumption data to account for atmospheric effects, it can be determined that Gardewine North has achieved an average corrected fleet fuel economy of 5.87 mpg (48 litres/100 km) by governing speed on its trucks at 55 mph (90 kmh).

4.2.2 Intra-Fleet Fuel Economy Variation

Although Gardewine's fleet is primarily equipped with Cummins engines and OEM road speed governors, the firm also operates a number of units equipped with CAT engines. The speed of vehicles equipped with CAT engines is cheaply and effectively controlled by governing engine speed through a screw on the fuel pump spring. This effectively acts as an engine speed governor. Fuel flow is restricted to allow an engine speed of 1700 RPM. Gardewine seals the screw with silicone to detect tampering.

In order to determine whether differences exist between the fuel economy achievable by CAT power units equipped with an engine speed governor (ESG) and Cummins power units equipped with a road speed governor (RSG),

Figure 1 - Gardewine North - Average Truck Fleet Fuel Efficiency Over Time
(Observed and Corrected for Atmospheric Effects)



the daily fuel economy of six fully loaded (in both directions) trucks of each type was recorded in March/April 1985:

	CAT (ESG)	CUMMINS (RSG)
Observed data in MPG (litres/100 km)	5.90 (47.9)	5.87 (48.1)
Data corrected for atmospheric effects in MPG (litres/100 km)	6.12 (46.1)	6.09 (46.4)

Analysis of the variability of the data indicates that there is no statistically significant difference between the fuel economy of CAT (ESG) and Cummins (RSG) equipped vehicles at Gardewine North.

Furthermore a comparison of older (a year old and more than 250,000 miles/ 400,000 km) versus newer (3 months old and less than 250,000 miles/ 400,000 km) trucks equipped with RPM-governed CAT engines shows no statistically significant difference.

	OLD CAT	NEW CAT
Observed data in MPG (l/100 km)	5.76	5.97
Data corrected for atmospheric effects in MPG (l/100 km)	6.04	6.16

In view of the fact that Gardewine achieves the same results with a relatively inexpensive (a simple part of the fuel pump) engine speed governor on CAT engines as with the more expensive ($640 OEM and $1,500 retrofit) road speed governor it would appear more logical to control speed and fuel economy using a sealed preset screw on the fuel pump to govern engine RPM's on all vehicles. However, as mentioned in Section 2 of this report, on certain engines, engine speed governor "droop" will allow a tractor an extra three to six miles per hour over the desired governed limit.

The CAT engines used by Gardewine are not affected by engine governor droop so that when a fuel pump spring screw used as an ESG is set so as to restrict engine speed to 1700 RPM, that engine speed is constantly maintained. The Cummins engine, however, has a built-in droop of 100

RPM (under light load and as low as 25 RPM under heavy load) which will cause top governed engine speed to fluctuate. Therefore, the more effective way of mechanically controlling speed on a Cummins engine is with a road speed rather than engine speed governor. Furthermore, with regard to governing engine speed on the CAT equipped trucks, there is a danger of engine damage under heavy load in lower gears as a result of restricting engine RPM's to a speed lower than the engine's design speed.

As an indicator of fuel economy achievable with road speed governors under different kinds of operating conditions, Gardewine also recorded daily fuel economy on four ore haul trucks in northern Manitoba. These units operating at a gross vehicle weight of 125,000 pounds (56.7 tonnes) were compared to line haul trucks with the same power train and governing system (Cummins) operating at a gross vehicle weight of 86,000 pounds (39 tonnes).

	ORE HAUL (125,000 lb. /56.7 tonne G.V.W.)	LINE HAUL (86,000 lb. /39 tonne G.V.W.)	% Difference
Observed data in MPG (litres/100 km)	4.99 (56.6)	5.87 (48.1)	17.6 (-15.0)
Data corrected for atmospheric effects in MPG (litres/100 km)	5.14 (54.9)	6.09 (46.4)	17.5 (-15.5)

The difference between the two groups of trucks is statistically significant at the 100 per cent confidence level and shows that an increase in load of 39,000 pounds (17.7 tonnes) reduces governed vehicle fuel economy by nearly a full mile per gallon (or increase of 8.5 litres per 100 kilometers).

4.2.4 TRW Electronic Truck Engine Control (ETEC)

The TRW ETEC system is an advanced technology electronic device which governs engine and road speed and features cruise control. Relatively new to the market the device has been successfully implemented on OEM International Harvester trucks. Gardewine North owns such a vehicle

equipped with a 300 Cummins engine and has purchased a number of ETEC units to be retrofitted on newly ordered Ford trucks with Cummins 350 formula engines. Gardewine's aim in installing these units is to achieve further fuel savings by smoothing out top road speed.

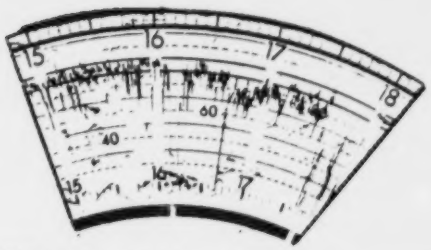
Tachograph card cuts in Figure 2 show the road speed in kilometers per hour of four trucks governed in four different ways. The very choppy speed graph of the ungoverned unit (1) is indicative of sporadic driving and inefficient fuel use. The unit (2) equipped with a screw-type ESG shows improvement in speed consistency and therefore fuel economy. Road speed consistency and fuel economy are further improved in the unit (3) equipped with a Cummins RSG. The very smooth (except for breaking and stops) road speed line shown by the unit (4) equipped with the ETEC system represents the saving that Gardewine North hopes to achieve over and above the fuel economy already presented by governing engine and/or road speed.

In order to demonstrate this potential saving, Gardewine was to have run tests as described in Section 4.2 of the report. ETEC systems were installed on 7 trucks, 6 of which were to be deployed on regular line-haul routes and 1 on the company's northern Manitoba ore haul. In the case of the first 6 units, fuel economy was to have been compared to other non-ETEC trucks. The fuel economy of the ore haul truck equipped with the seventh unit was to have been compared to an identical but ungoverned ore haul truck.

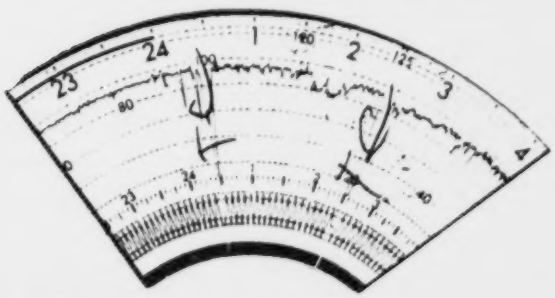
Following installation of devices, Gardewine's fleet manager took some of the units on test runs. The unit functioned properly as a road speed governor until the cruise control (the item expected to deliver the additional savings) was set. As soon as the cruise control was activated, it deprived the road speed governor unit of air causing the engine to surge. After much investigation, analysis, testing and a visit from a TRW representative (there is currently no approved supplier in Winnipeg), it was discovered that the cruise control was shorting out because of its installed position in the tractor. Two of the units were repositioned and preliminary road tests showed the ETEC system to be working properly. At the time of writing, the ETEC tests have not been conducted by Gardewine. It is anticipated that installation problems will be corrected and test results will be available by the Fall of 1985.

Figure 2: TYPICAL TACHOGRAPH READINGS UNDER ALTERNATIVE GOVERNING SYSTEMS*

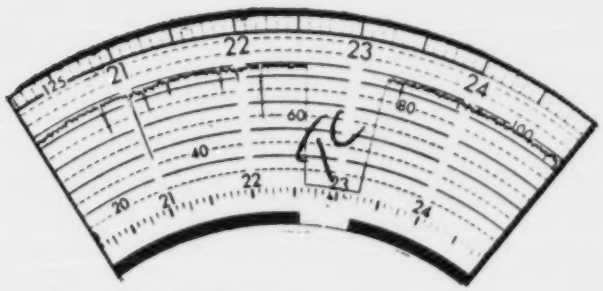
1. UNGOVERNED



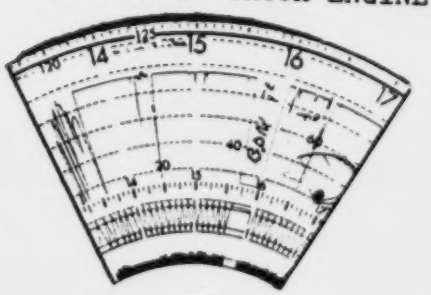
2. PRESET SEALED GOVERNOR SCREW (ENGINE SPEED GOVERNOR)



3. CUMMINS OEM ROAD SPEED GOVERNOR



4. TRW ELECTRONIC TRUCK ENGINE CONTROL



* Source: Gardewine North, April, 1985

4.3 Canada Safeway Ltd. Trucking Department

Recognizing the importance of reducing fuel consumption, Safeway introduced radial tires to its highway fleet in late 1981 and early 1982. The company's Winnipeg-based fleet manager was also concerned about industry reports that operating costs double in all respects when highway speeds average 70 miles per hour (112 kmh) as opposed to 55 mph (90 kmh). For example, half of the company's mileage consists of empty returns, and aside from the fact that fuel is wasted, high speeds are very tough on tires and suspensions. Therefore in 1982 the company began a moral suasion policy to encourage drivers to reduce speed. However the drivers were not persuaded to slow down and in spring of 1983 the company began a program of governing speed mechanically by retrofitting its trucks with Cummins Road Speed Governors at the rate of one per week until the entire fleet was governed at 55 mph (90 kmh). Any new trucks purchased are equipped with OEM Cummins RSG's.

Aside from governing speed there have been no significant changes in Safeway's fleet or its deployment since 1982. Because 1983 was a year of transition (i.e., the period during which governors were gradually installed), a comparison of operating costs between 1982 and 1984 best illustrates the savings Safeway has achieved by governing speed. Canada Safeway reports significant savings which they attribute to governing speed in several areas:

1. Direct Fuel Consumption Savings Due to Road Speed Governors:

	1982	1984	% Change
Miles Travelled	1,982,799	2,231,916	12.6%
(kilometers)	3,191,012	3,591,927	12.6%
Gallons Consumed	351,469	359,890	2.4%
(litres)	1,597,586	1,603,146	2.4%
Miles per Gallon	5.64	6.20	9.9%
(litres per 100 kilometers)	50.07	45.55	-9.0%
Cost per Mile (at $2.10/gallon)	37.2¢	33.9¢	-8.9%
(cost per km @ $0.462/litre	23.1¢	21.1¢	-8.9%

If Canada Safeway had not introduced road speed governors and continued with its 1982 fuel economy of 5.64 mpg (50 litres per 100 km), in 1984, 395,730 gallons (1,762,797 litres) of diesel fuel would have been required for the 2,231 916 miles (3,591,927 km) travelled in 1984. Safeway thus considers itself as having saved (395,730-359,890 =) 35,840 gallons (162,909 litres) for 1984 alone.

At current costs of approximately $2.10 per gallon ($0.462/litre), this means Canada Safeway's Manitoba/Saskatchewan Division alone saved $75,264 in fuel costs.

2. Indirect Tire and Maintenance Savings Due to Road Speed Governors:

	1982	1984	% Change
Repairs and Maintenance Costs	$465,558	$525,780	+12.9%
Tires	57,116	54,254	- 5.0%
Tires and Maintenance	522,674	580,034	+10.9%
Costs Per Mile	26.4¢	26.0¢	- 0.4%
Costs per Kilometre	16.4¢	16.2¢	- 0.4%

Tire costs have declined and repair and maintenance costs have risen during a period in which miles travelled also increased. The overall result has been that tire and maintenance costs per mile have declined slightly.

3. Overall Effect of Road Speed Governors on Highway Operating Cost:

	Costs per Mile (per kilometer)		
	1982	1984	% Change
Fuel	37.2 (23.1)	33.9 (21.1)	-8.9%
Maintenance and tires	26.4 (16.4)	26.0 (16.2)	-0.4%
	63.6 (39.5)	59.9 (37.3)	-5.8%

Canada Safeway has therefore reduced its highway operating costs by 3.7 cents per mile (2.2¢/km) as a result of introducing road speed governors.

4. Pay Back Analysis

Given these reduced highway operating costs, Safeway saved $82,851 in 1984 alone by governing speed. The installation of Cummins retrofit governors on 20 units at $1,500 each in 1983 cost the company $30,000. This means that the company saved 2.75 times its initial investment in 1984 alone. Safeway's Manitoba/Saskatchewan fleet manager estimates that the investment in each retrofit governor is recovered in a period of six months.

5. ECONOMIC BENEFITS AND FUTURE POTENTIAL

Discussion of the results of the energy conservation efforts of three motor carriers in Section 4 reveals that there are varying levels of fuel economy improvement that can be achieved by governing speed and or introducing other energy conservation techniques such as wind deflectors, radial tires, formula engines.

1) If none of these techniques are used truckers can expect an average fleet fuel economy in the neighbourhood of 4 miles per gallon (70.6 litres per 100 kilometers) on line haul trucks operating at 86,000 pounds (39 tonnes) gross vehicle weight. If a road speed governor is added, fuel economy can improve to 5 mpg (56.6 litres/100 km).

2) As shown by Canada Safeway, introducing radial tires can improve fuel economy to 5 mpg (56.5 litres/100 km) while also adding on road speed governors can raise fuel economy further to 6 mpg (57 litres/100 km).

3) If road speed is kept down to 55 mph (90 kmh), whether this is done through effective moral suasion on drivers or strict enforcement of company speed policies based on tachograph or trip recorder readings, the addition of electro-mechanical road speed governors will not yield significant fuel savings over and above those already being achieved by governing speed in non-mechanical manners.

It is therefore difficult to estimate the exact benefits that can be achieved through the universal introduction of road speed governors because many Canadian motor carriers have taken a variety of combinations of fuel conservation measures to reduce their highway operating costs. However, the intermediate (in terms of fuel savings) case of Canada Safeway is instructive for the purpose of estimating benefits that can be achieved by introducing road speed governors. As shown in Section 4.3 this firm improved its fleet fuel economy to 5.64 mpg (50 litres/100 km) by introducing radial tires - a "first generation" type of fuel conservation measure. They then implemented a road speed governor program which yielded a fleet fuel economy of 6.2 mpg (45.5 litres/100 km). Using this improvement of 0.56 mpg (4.5 litres/100 km), it is possible to make a

rough estimation of how much fuel can be saved by Canadian truckers if road speed governors were to be introduced universally on commercial trucks in Canada; such an estimation takes into account that some motor carriers are currently using no energy conservation practices whatsoever while others are much more advanced in this regard.

To determine the Canadian universe of relevant trucks - that is, the target market for road speed governors - data on vehicle registrations from the Manitoba Motor Vehicle Branch were used. In 1982, 187,083 trucks of all types were registered in Manitoba. Of these, 17.61 per cent (32,945) were trucks at gross vehicle weights of 17,600 pounds (8,000 kilograms) or more; smaller trucks are more likely used in urban pick-up and delivery applications or for passenger purposes. Within this number 17.84% (5,877) were registered as commercial or for hire trucks. Applying these percentages to Statistics Canada data on vehicle registrations in all provinces in Canada, it is estimated (Table 1) that there are 101,768 commercial and for hire trucks in Canada to which road speed governors could be applied. A survey of Manitoba motor carriers indicates that only 5% of the Manitoba commercial and for hire fleets use RSG's. If this figure can be applied to the Canadian fleet, it can then be assumed that only 5,088 trucks in Canada are equipped with road speed governors, leaving a potential for 96,680 commercial and for hire trucks to save fuel by installing road speed governors.

Retrofitting all 96,680 trucks with road speed governors could cost in the neighbourhood of $145 million at $1,500 per unit. Using the above-mentioned intermediate level saving achieved by Canada Safeway of 0.56 mpg (4.5 litres/100 km) and assuming that each truck travels an average of 100,000 miles (160,935 km) per year, the installation of road speed governors on 96,680 ungoverned commercial and for hire trucks each would save 1,601.5 gallons (7,279.5 litres) or an annual Canadian fleet total of 154,833,020 gallons (703,786,454 litres). At a current cost of $2.10 per gallon ($0.462/litre) the total value of the fuel saved would amount to $325,149,342. This saving is more than double the amount that would have to be spent on retrofitting the Canadian commercial and for hire fleet with road speed governors in the installation year alone.

Table 1: Estimation of Canadian Market Potential for Road Speed Governors*

	(a) Number of Trucks Registered (All Sizes)	(b) Number of Trucks Over 8,000 kg. Gross Vehicle Weight	(c) Number of Commercial and For Hire Trucks Over 8,000 kg. G.V.W.
Newfoundland	56,440	9,939	1,773
P.E.I.	17,397	3,064	547
Nova Scotia	147,691	26,008	4,640
New Brunswick	99,523	17,526	3,127
Quebec	294,706	51,898	9,259
Ontario	1,067,535	187,993	33,538
Manitoba	187,083	32,945	5,877
Saskatchewan	294,904	51,933	9,265
Alberta	460,217	81,044	14,458
British Columbia	591,925	104,235	18,596
Yukon	11,358	2,000	357
N.W.T.	10,562	1,860	332
Canada Total	3,239,341	570,448	101,768

* Notes: a) Derived from Statistics Canada 53-219, Road Motor Vehicles: Registrations, 1982.

b) Using Manitoba Motor Vehicle Branch registration files (documented in "The Task Force Review of Motor Carrier Regulations in Manitoba - Background Report"), a proxy figure of 17.61% of all trucks registered with gross vehicle weights over 8,000 kg. (17,636 lbs.) was developed for application to all trucks registered in all provinces.

c) Using the same source as in (b) a proxy figure of 17.84% of all trucks over 8,000 GVW being commercial and for hire trucks was developed for application against figures shown in column (b).

6. CONCLUSIONS

The different results achieved by the three motor carriers participating in this demonstration project do not yield a sweeping general conclusion concerning the fuel economy improvement that a motor carrier installing road speed governors can expect. This is because of the different policies each company had toward speed before governors were installed. In the case of Canada Safeway where speed had not been previously controlled, dramatic improvements were achieved by installing road speed governors. Canadian Motorways' longstanding speed policy, initially implemented primarily for safety reasons, has been relatively effective in controlling both speed and fuel consumption without road speed governors. At Gardewine North, governing speed mechanically (and now electronically) has been a policy for years.

Whether add-on devices are involved or not it is clear that maintaining speed at 55 mph (90 km) has resulted in average fleet fuel economies of approximately 6 miles per gallon (47 litres/100 km) at the three motor carriers studied. Although not the subject of examination in this project, radial tires are thought to have contributed an important element in the 6 mpg (47 l/100 km) fuel economy level. Moreover, firms not using road speed governors or radial tires are more likely to receive fuel economy in the neighbourhood of 4 mpg (70.6 litres/100 kilometers).

While all energy conscious fleet managers agree that maintaining speed at or below 55 mph (47 litres/100 km) is a vital element in achieving desired fuel efficiency levels, different companies prefer different options for controlling speed. Depending on time and money available, a company can choose to reduce speed and fuel consumption in any of the following ways:

- installation of electro-mechanical devices such as the Cummins Road Speed Governor and the TRW electronic engine control;
- strict enforcement of tachograph or trip recorder readings;
- provision of financial rewards/incentives to drivers achieving high fuel economy levels; and,
- use of penalties for drivers achieving poor fuel economy levels.

The importance of such fuel conservation measures can be illustrated by considering two identical fleets both operating 10 tractors over similar routes and loads at 100,000 miles (160,000 km) per year each. Fleet A consists of conventional trucks with formula engines equipped with road speed governors and using radial tires. Fleet B consists of a mixture of older cabovers and conventionals, running on ordinary tires and the company has no policy or devices for controlling speed.

	Fleet A	Fleet B
Number of tractors	10	10
Annual fleet miles (kilometers)	1,000,000 (1,600,000)	1,000,000 (1,600,000)
Average fleet fuel economy in miles per gallon (litres/100 km)	6 (47)	4 (70)
Annual gallons consumed (litres)	166,667 (757,577)	250,000 (1,136,364)
Annual fuel cost at $2.10 gallon (46¢/litre)	$350,000	$525,000

From the above calculations, it can be seen that the energy conscious operators of Fleet A pocket $175,000 more of their earned revenues than do the operators of Fleet B. In these circumstances, the cost and benefits of implementing any of the above-mentioned measures (including the installation of speed controls and radial tires) warrant serious examination by any motor carrier currently achieving less than 6 miles per gallon (47 litres/100 km).

APPENDIX A

LIST OF COMPANIES INVOLVED IN THIS DEMONSTRATION PROJECT

A number of Manitoba trucking companies were approached to demonstrate the energy conservation potential of road speed governors and anti-idling devices. Some of these declined participation for a variety of reasons, others agreed to participate but eventually withdrew, and three companies cooperated fully.

A.1 COMPANIES DECLINING PARTICIPATION

Name	Test Type	
	Road Speed Governor	Anti-Idling Device
Argosy Trucking	X	
Associated Beer Distributors		X
Audley Cartage		X
Burns Meats	X	X
CN Route		X
Eaton's		X
Greater Winnipeg Gas		X
Jessiman Bros. Cartage		X
Klassen Trucking	X	
Manitoba Hydro		X
Rolly's Transfer		X

A.2 COMPANIES WITHDRAWING PARTICIPATION

Name	Test Type	
	Road Speed Governor	Anti-Idling Device
Bison Transport	X	
Bulk Milk Haulers	X	
Canada Messenger		X
Canadian Motorways (AID only)		X
Kleyssen's Transport	X	
Reimer Express Lines	X	X
Simonson Transport	X	

A.3 FINAL PARTICIPANTS DEMONSTRATING THE ENERGY CONSERVATION POTENTIAL OF ROAD SPEED GOVERNORS

Name and Address	Contact	Phone
Canadian Motorways Ltd. 60 Eagle Drive P.O. Box 738 Winnipeg, Manitoba R3C 2L8	Mr. J. Attenborrow	(204) 633-5560
Gardewine North 300 Oak Point Road Winnipeg, Manitoba R2R 1V1	Mr. W. Francis	(204) 633-5795
Canada Safeway Ltd. Trucking Department 1100 King Edward Street Winnipeg, Manitoba R3H 0R2	Mr. J. Faas	(204) 633-7296

APPENDIX B

DETAILS ON THE CUMMINS ROAD SPEED GOVERNOR
AND BIG CAM III FORMULA 350 ENGINE
(COMPANY LITERATURE)

Automotive Marketing Bulletin

date July, 1978
no. 78-22
file 01.127

subject: ROAD SPEED GOVERNORS

to: All U.S. and Canadian Distributors

This bulletin has been issued to explain what a "Road Speed Governor" is and what it can do -- along with a progress report on the Cummins Road Speed Governor. The attachments to this bulletin form a presentation you can use in explaining this information to others. The text of this bulletin discusses in detail the information we are trying to convey on each slide.

Part I, Slides 1-6

This portion of the presentation covers the basic concept of the Road Speed Governor (RSG) and what it can do.

Slide 1: Background and Setting the Stage

The RSG is not a new idea; it has been used before. Cummins offered an RSG once before, but it was not a successful project - for two basic reasons: First, the hardware was not reliable or designed to be tamper resistant (an air cylinder with exposed linkage was used on the fuel pump). It relied on a signal from the transmission for actuation, and the hardware on the transmission was not properly designed either. (The driver could defeat the governor by running with the transmission partially engaged, which also led to gearbox failures.) Second, the concept was applied to vehicles with marginal power (engines in the 180-240 hp range) so the driver's job was made very difficult. Also, the modern interstate highway system was not available to allow sustained cruise operation at relatively modest power levels.

The basic concept was sound, but there was not a high level of concern about and dedication to saving fuel - fuel was cheap, productivity was usually more important - so the project lapsed. The situation has changed -- fuel is expensive and will get more costly. Most fleet operators are caught in an ever tightening squeeze with costs (all costs, not just fuel) rising faster than revenues. Most operators today regard improved fuel economy as a major opportunity to reduce costs and have come to recognize road

speed as the major determinant of fuel economy.

Other factors in the general climate of truck operations have also changed. The modern truck engine is more powerful (270-350 hp is typical now) and is turbocharged -- operating it efficiently means getting good fuel economy at part load which means reduced speed. The "Formula" concept (reduced rated rpm) gets about half of the potential available from slowing the engine down; best efficiency occurs at even lower rpm. The additional power in today's trucks makes operation at reduced rpm more practical. Finally, the trucking industry faces a very real public image problem -- many trucks are operating at 5-10 mph above the national 55 mph speed limit, and some are running faster.

The trucking industry is more receptive to the idea of limiting truck operating speeds today, and the RSG is one way to do this.

Slide 2: Methods of Controlling Truck Speeds

There are three basic approaches to limiting truck speed. First is the method traditionally used in U.S. trucking -- select the axle ratio and tire size that allow the engine high speed governor to cut off power and limit the truck to the desired road speed. It is inexpensive, requiring no extra hardware (a high speed governor is standard on all diesel engines). It is also easy to drive; the driver puts the throttle pedal on the floor and cruises. When he hits a hill he has the full operating speed range of the engine to work with before a downshift is forced. Unfortunately, operating the engine this way does not give best engine efficiency. The use of "Formula" ratings helps, but still leaves an engine 200 to 300 rpm above its most efficient rpm. It is not feasible to set the engine governor at the most efficient rpm, as this leaves an inadequate rpm range to match the transmission when operating below cruise speed.

One way to limit cruise speed to the engine's most efficient rpm is to use a Road Speed Governor. An RSG is a governor that acts independently of the engine high speed governor to limit engine speed in top gear, thereby limiting road speed. This has the advantage of keeping the engine at its most efficient rpm in top gear (which cannot be done with the engine governor) and still allows full performance in lower gears. The disadvantage is that it makes the truck more costly (additional hardware to buy and maintain). Nobody has devised a "tamperproof" RSG, but the systems available today, or coming to market, are a significant improvement over earlier systems. Despite the improved power and less

demanding road conditions of today, driving an RSG limited truck is harder work than driving the same truck without the RSG. The truck cannot get as fast a "run" at hills when limited by the RSG, so the driver is forced to shift more often.

The RSG is one approach to obtaining reduced speed operation; the other is to obtain driver cooperation ("professional" behavior) without special hardware that has direct control of the truck. This approach emphasizes voluntary effort by the driver, sometimes reinforced by use of incentives, tachographs, and/or in-the-field supervision of some sort. Hardware and other costs are nonexistent, or relatively modest. Little or nothing restrains the driver in a direct way; if he decides not to cooperate he opens the throttle and drives faster. If the driver cooperates by driving the truck slow, he faces the same increase in shift frequency as he would on an RSG equipped truck plus the burden of watching the speedometer and modulating the throttle to hold the desired cruise speed -- a "cruise control" can help by assuming this job for him.

Slide 3: Trade-off of Economy versus Productivity

This slide, and the next two, show the basic factors the operator must work with in deciding how to go after speed control. For any basic vehicle specification, there is a characteristic relationship between productivity (average road speed) and operating cost (fuel economy). The faster the truck runs, the lower the fuel economy. This particular chart is for a typical U.S. combination and shows a trend that is typical of line haul trucking -- a straight line relationship between average speed (mph) and fuel economy (mpg) with a slope (sensitivity) of about 0.1 mpg per 1.0 mph. These results were generated by VMS using a typical interstate highway (the trend line was produced by progressively reducing maximum or "cruise" speed), and experience confirms their validity. The operator must decide what balance he needs between productivity and fuel cost; in other words, he must decide where on this line he wants to operate. The trend today is to optimize fuel economy and accept the loss in average speed. Note that average speed as shown here represents actual driving time, not necessarily total trip time. The difference is the time the driver spends for rest stops, refueling, etc.

Slide 4: Effect of Engine Governed Speed

This shows the point at which the truck actually operates, depending on governed speed of the engine to limit truck speed. The slower the governed engine speed, the slower the average speed and the better the fuel economy. The 1800 rpm version of the Formula 290 is almost at the same point as observing a 55 mph limit - which is the speed at which the Federal government feels everyone should operate. At this point, one might well ask why consider using Road Speed Governors; why not use the combination of engine governed speed, axle ratio, and tire size that gives the desired road speed, and run there? The answer is that it is possible to set up a more efficient basic vehicle specification, as shown in the next slide.

Slide 5: Alternate Specification with Faster Axle

Here, the fuel/speed trade-off characteristic for a 4.11 axle ratio is compared to what is possible with a 3.70 axle. Because of the efficiency characteristics of turbocharged engines, and the fact that engine rpm is slower at any given road speed with a 3.70 compared to a 4.11 axle, the results achievable with the 3.70 axle are superior. Equally important, road speed is higher (and fuel economy is lower) at the point where the engine governor controls the operation for the 3.70 axle compared to the 4.11 axle. To approach the 55 mph goal, and realize the potential benefits of the faster axle ratio, it is necessary to control maximum road speed some other way than using the engine high speed governor. This is where alternate methods of controlling road speed come into play, including the road speed governor. With the Big Cam engine, the potential benefit is .15-.20 mpg (it was a bigger difference for the small cam engines). This must be considered against the cost and/or exposure inherent in using something besides the engine high speed governor and an axle ratio that compromises potential efficiency.

Slide 6: RSG versus Cruise Control

There is often confusion between these devices. This slide is intended to clarify the situation. A cruise control is intended to make life easier for the driver by relieving him of the need to modulate the throttle to maintain a fixed, reduced cruise speed. The driver controls the speed setting and is free to use it or not, as he desires. There is no need to make such a device tamper resistant, for the driver will feel no pressure to meddle with it.

A road speed governor, on the other hand, is not intended to make life easier for the driver. It is imposed on a driver who otherwise would drive the truck faster than the RSG will allow. The driver has no choice about using it; he must live with it unless he can find a way to overcome it. For this reason, an RSG must be designed to be tamper resistant (there is no such thing as "tamperproof"), and periodic checks will be needed to make sure it continues to function.

Part II, Slides 7-2

The remaining five slides are an explanation of the Cummins RSG system.

Slide 7: The Cummins Road Speed Governor

Production availability is estimated for approximately January 1, 1979 (pending successful field and bench tests of the latest proposed hardware). It can be used on any Cummins engine (capable of accepting the VS-type governor). Fuller Transmission has released hardware for all transmission models that are likely candidates. Spicer has basic provision in its heavy duty transmissions, but has not released specific parts to complete the adaptation. Allison has the capability of providing the signal needed and are awaiting a governor from us so they can proceed. In general, it will be possible to use the RSG with any heavy duty engine/transmission combination, but close step transmissions will probably not be a practical application.

The reduced speed setting is whatever the operator desires. The engine will nominally be set to cut off 200 rpm below the nominal rated engine speed, but the operator can adjust this as required. Remember when specifying the truck that if the RSG is set too slow then the driver can defeat the objective of reduced speed by not using top gear. In practical terms, this means setting the governor at least 3-4 mph above geared speed in next-to-top gear.

Costs shown are estimates, subject to final decision on prices by Cummins - and what the OEM actually chooses to charge.

The Cummins RSG uses the standard production VS governor, so its ability to function as a full range governor is lost. Full range governor capability adequate for moderate PTO power requirements and fast idle (for cold weather needs) can be supplied at extra cost as a retrofit. (This requires use of the old SVS or remote MVS governors, which will continue to be available for service only. It is assumed that demand will be a low for RSG with full range governor capabilities; more

normal arrangements for availability can be made if this assumption is wrong.)

Slide 8: Cummins RSG System Schematic

The basic system is simple, a special fuel pump incorporating a modified VS governor and a control valve assembly on the transmission with an air line connecting them. (If the transmission is not equipped with an air shift system, provision is needed to supply air from the truck air system.) The control valves on the transmission are arranged so a positive air pressure signal is supplied in all gears except top gear -- in top gear, the air signal is shut off. The RSG on the fuel pump allows operation up to nominal rated engine speed whenever it sees a positive air pressure and cuts the engine off at a predetermined (adjustable) reduced speed when the air signal is off. This speed, as translated by the axle ratio and tire size, corresponds to the maximum powered road speed the operator desires.

Slide 9: Cummins RSG Operating Principle

This slide shows the basic mechanism of the governor, PTG-VS fuel pump, with a special housing (containing the air actuated piston, adjusting screw, and air signal fitting) replacing the normal VS fuel pump operating lever housing. The top drawing shows the major components and their working relationship. The flyball assembly, plunger, housing and spring are standard VS governor parts.

Fuel leaves the normal automotive section of the pump (where the high speed governor and power curve shape is determined) and passes through the throttle section of the VS governor. As the second illustration shows, when the air signal is off the air piston is bottomed out against the low speed adjusting screw. At the desired (reduced) engine speed, the balance between the spring force (controlled by piston position, which is controlled by the adjusting screw) and the flyball assembly force positions the governor plunger so it cuts off (restricts) the fuel going to the injectors. Once the operator has adjusted the RSG to the desired speed, further tamper resistance is provided by a swaged-in-place washer to prevent unauthorized access to the adjusting screw.

In lower gears, when a positive air signal is provided, the piston is forced away from the low speed screw. This provides enough force on the governor plunger (through the spring) to keep the flyball assembly from moving the plunger over and restricting fuel flow. The normal automotive high speed governor now controls maximum engine speed.

Slide 10: Cummins RSG Signal System - Simple Gearboxes

The signal to the RSG is controlled by a three way valve on the transmission, actuated by the top gear shift rail. In lower gears, the valve connects the air supply to the air signal line and provides a positive air signal. In top gear, the valve plunger is mechanically shifted by the ramp on the top gear shift rail so that the air supply is blocked off, and the air signal line is connected to an exhaust port to eliminate the air signal to the engine. On Allison automatics, the valve will be actuated by a hydraulic signal rather than a mechanical shift rail.

Slide 11: Cummins RSG Signal System - Compound Gearboxes

On most transmissions used with Cummins engines, a somewhat more complicated system is needed so that the governor will not engage in one of the lower gears (in a compound gearbox, top gear in the main box is used more than once). As this slide shows, a shuttle valve is used so that the three way valve on the top gear shift rail and/or the air signal that holds low range engaged is used -- both must be off before the engine sees a loss of air signal and cuts back governed speed.

A follow-up bulletin covering actual production dates along with specific part numbers and prices will be issued when the situation is more settled.

jmf

Attachments

Cummins Engine Company, Inc.
Automotive Marketing

K.J. (KEN) TANNER
General Sales Manager

Cummins Mid-Canada Ltd
489 Oak Point Road
Winnipeg, Manitoba R3C 3R1
Bus (204) 632-5470
Res (204) 885-6926

Pager 942-3108
code 2367

ROAD SPEED GOVERNORS

OPTIONS FOR TRUCK SPEED CONTROL

ENGINE GOVERNOR AS ROAD SPEED GOVERNOR,
USE GEARING TO CONTROL

- TRADITIONAL APPROACH, MOST COMMONLY USED
- LOWEST COST, MOST CERTAIN
- ENCOURAGES INEFFICIENT ENGINE OPERATION,
  REDUCED RPM SETTINGS HELP
  BUT COMPROMISE PERFORMANCE

ROAD SPEED GOVERNOR - CONTROL ROAD SPEED TO SOME
VALUE BELOW GEARED ROAD SPEED

- EXTRA COST, COMPLEXITY; NOT TAMPERPROOF
- ALLOWS EFFICIENT ENGINE OPERATION WITH
  POSITIVE CONTROL
- HARDER TO DRIVE, MORE SHIFTING

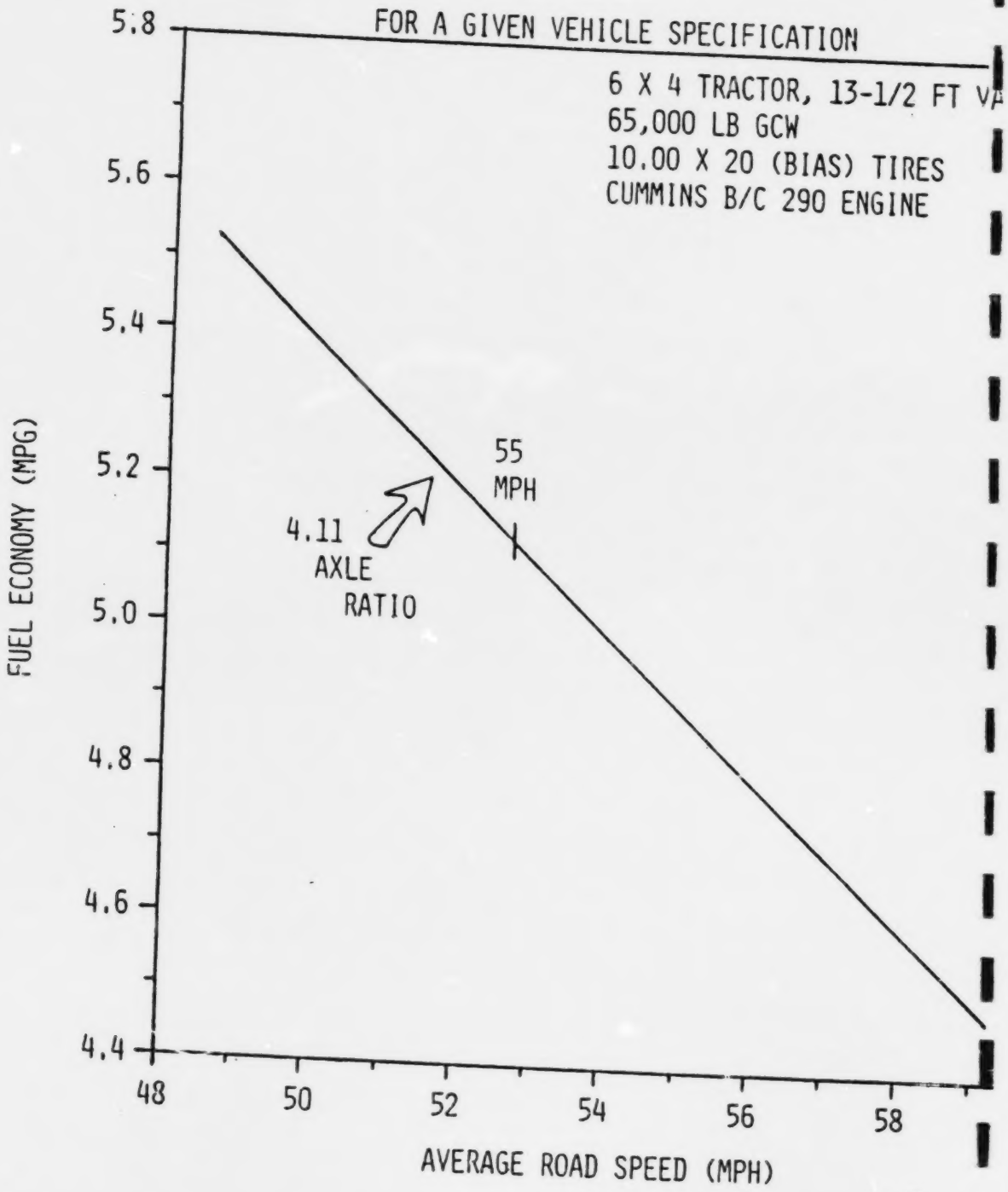
DRIVER PROFESSIONALISM - MAKE DRIVER PART OF SOLUTION

- NO EXTRA COST, NO ASSURANCE
- ALLOWS EFFICIENT ENGINE OPERATION
- HARDER TO DRIVE, MORE SHIFTING
- CRUISE CONTROL CAN HELP

OPERATING COST VERSUS PRODUCTIVITY

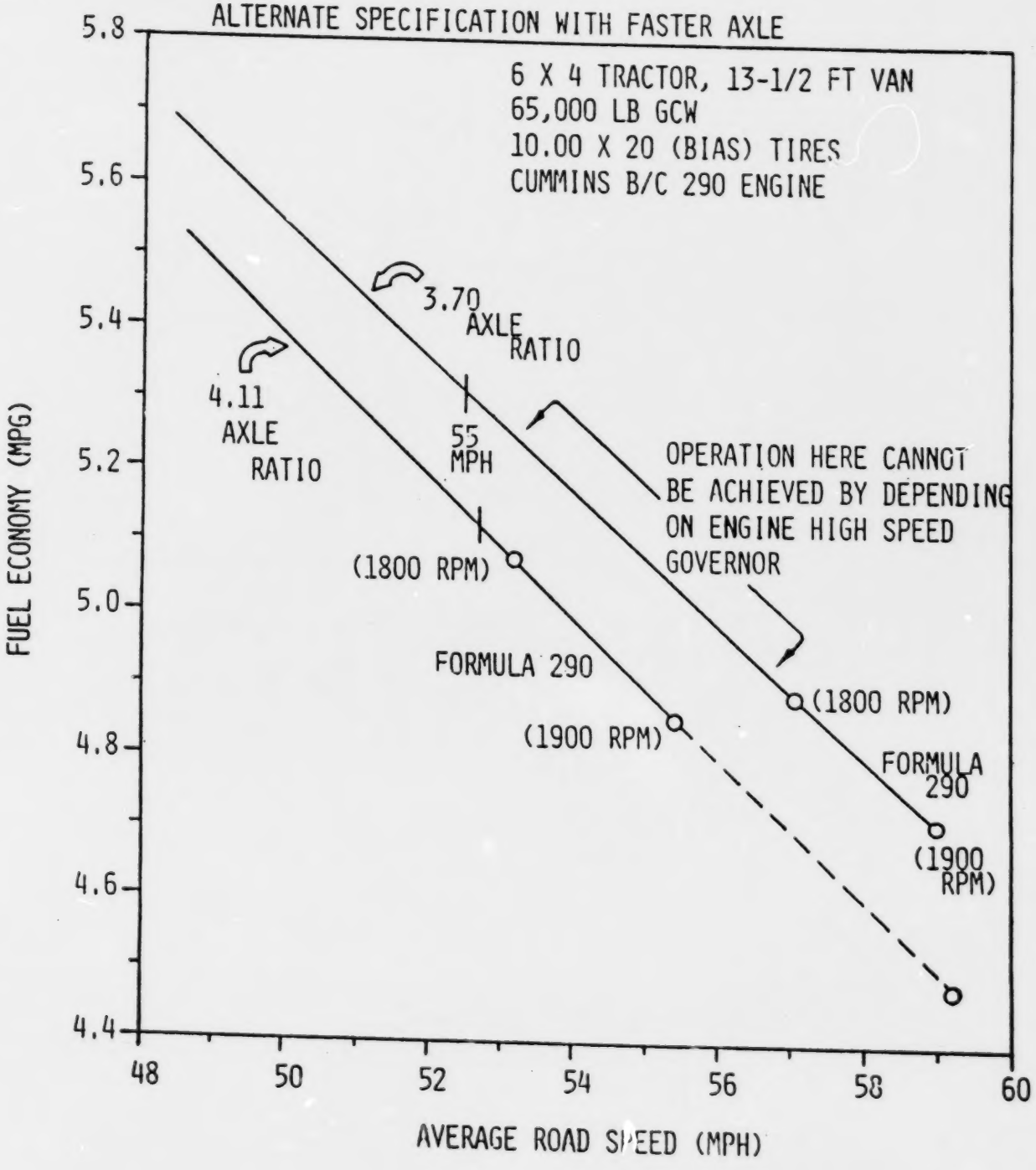
BASIC TRADE-OFF

FOR A GIVEN VEHICLE SPECIFICATION



OPERATING COST VERSUS PRODUCTIVITY

BASIC TRADE-OFF



CUMMINS ROAD SPEED GOVERNOR

AVAILABILITY (APPROXIMATELY) - JANUARY 1, 1979

- ANY ENGINE MODEL
- ANY TRANSMISSION (NOT RECOMMENDED FOR CLOSE STEP GEARBOXES LIKE RTO-9513, 1214-2A/3A)

REDUCED SPEED SETTING - ANY SPEED BELOW RATED ENGINE SPEED, AS REQUIRED

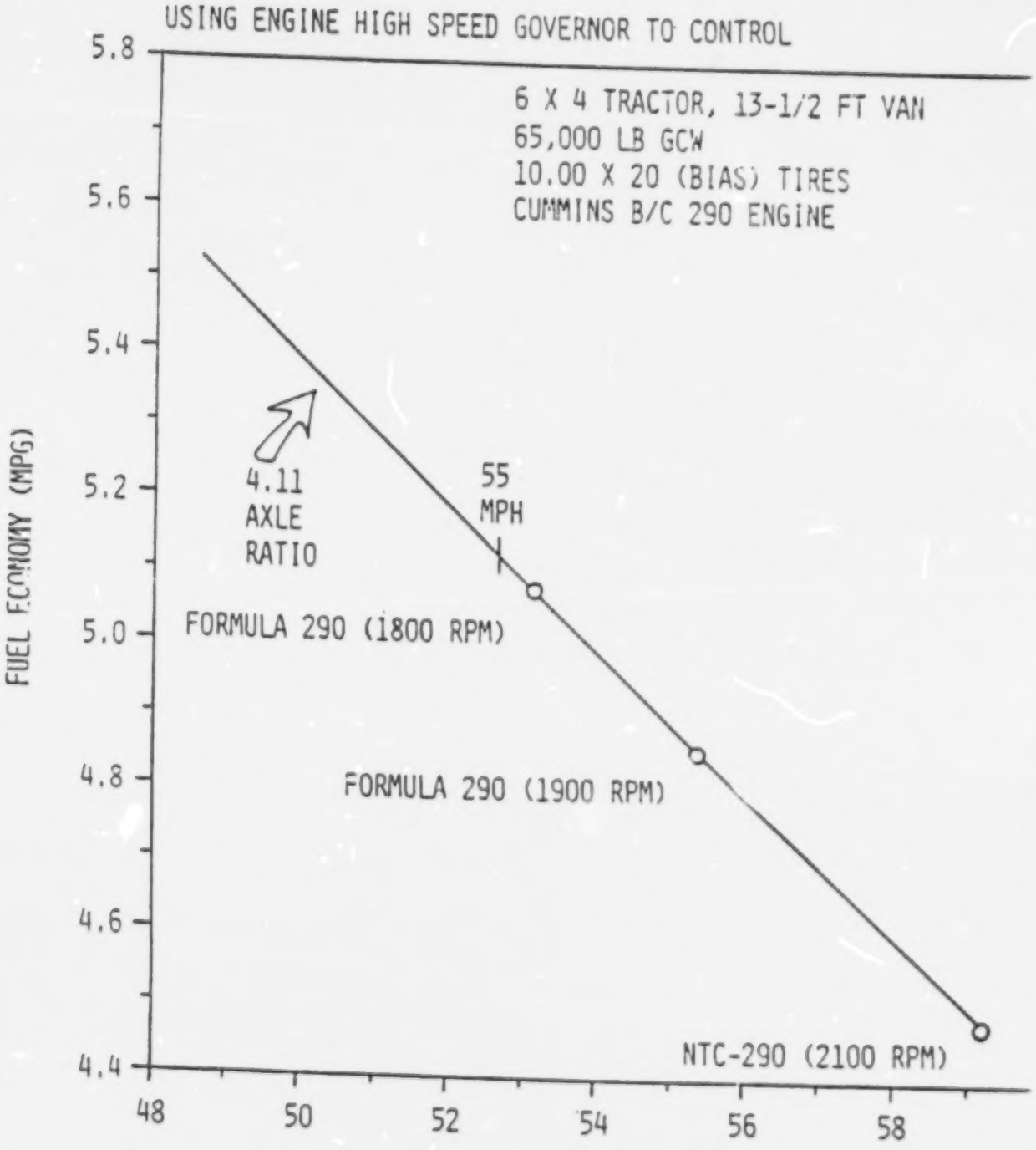
COST (ESTIMATED)

- NEW TRUCK, FROM OEM - $500 ± $50
- RETROFIT ON EXISTING TRUCK - $700 ± $50

RESTRICTIONS - NORMAL FULL RANGE GOVERNOR NOT AVAILABLE; CAN PROVIDE CAPABILITY AT EXTRA COST

OPERATING COST VERSUS PRODUCTIVITY

BASIC TRADE-OFF



ROAD SPEED GOVERNORS

"ROAD SPEED GOVERNOR" VERSUS "CRUISE CONTROL"

CRUISE CONTROL - TAKES OVER JOB OF MODULATING THROTTLE TO HOLD CONSISTENT CRUISE SPEED. CAN BE TURNED ON OR OFF AS DRIVER WISHES. THE SPEED SETTING IS AT THE DRIVER'S OPTION. INTENT IS TO MAKE DRIVING EASIER/MORE FUN.

ROAD SPEED GOVERNOR - PURPOSE IS TO LIMIT MAXIMUM ROAD SPEED, USED BECAUSE THE DRIVER WILL NOT DO SO VOLUNTARILY. NO OPTION AS TO WHETHER IT IS ON OR OFF, OR WHAT SPEED SETTING IS. TAMPER RESISTANCE IS IMPORTANT; IT IS BEING IMPOSED ON AN UNWILLING DRIVER.

L-480 ROADSPEED GOVERNOR INSTALLATION INSTRUCTIONS

1. Remove transmission shift bar housing and completely disassemble. Put aside shift bar housing and 4th and 5th shift bar.

2. Reassemble with new shift bar housing and 4th and 5th shift bar. The new shift bar is longer and has a recessed notch to accept the pin that actuates the part 18734 valve. The notch must face to the front of the shift bar housing when assembled and below the machined hole in the new housing.

3. Install new shift bar housing on transmission.

4. Remove low range hose from the elbow at the base of the range slave valve. Install one each of part 12769 nipple and part 12881 tee. Reinstall low range hose to end of tee. Install one 85002 elbow connector to center of tee.

5. Remove range valve supply line and connector elbow from front top of range slave valve. Install one each of part 12769 nipple and part 12881 tee in slave valve. Reinstall range valve connector elbow and supply line to rear of 12881 tee. Install one 85002 elbow connector to front of tee.

6. Install part 15899 valve actuating pin in open port of bar housing over the notched 4th and 5th shift bar.

7. Install two parts 85002 elbow line connectors in ports NC and CYL of part 18734 valve. Install valve to machined portion of shift bar housing using plate and ⅜" X 2" capscrews provided. NC opening should be facing rear towards slave valve tee installed in paragraph #5.

8. Install two part 84002 straight connectors in each end of part 18675 shuttle valve. Install one 85002 elbow connector in center of shuttle valve. Install shuttle valve to part 18685 bracket using U-bolt, nuts and washers.

9. Install bracket with shuttle valve to left hand front corner of shift bar housing using furnished 1¼" X 3/8" capscrews.

10. Install Nylaflow line between connector at tee on low range hose to connector at rear of shuttle valve.

11. Install Nylaflow line between connector at front of shuttle valve to connector at CYL port of part 18734 valve.

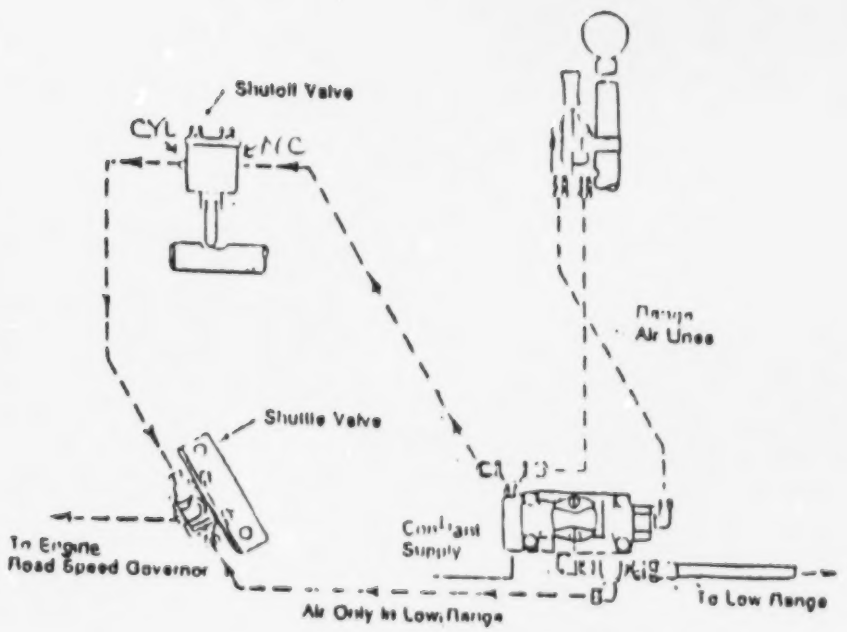
12. Install Nylaflow line between connector on NC of valve and connector in tee at range slave valve supply line.

13. From top remaining part 85002 elbow connector in shuttle valve run Nylaflow line to governor control on engine.

L-480

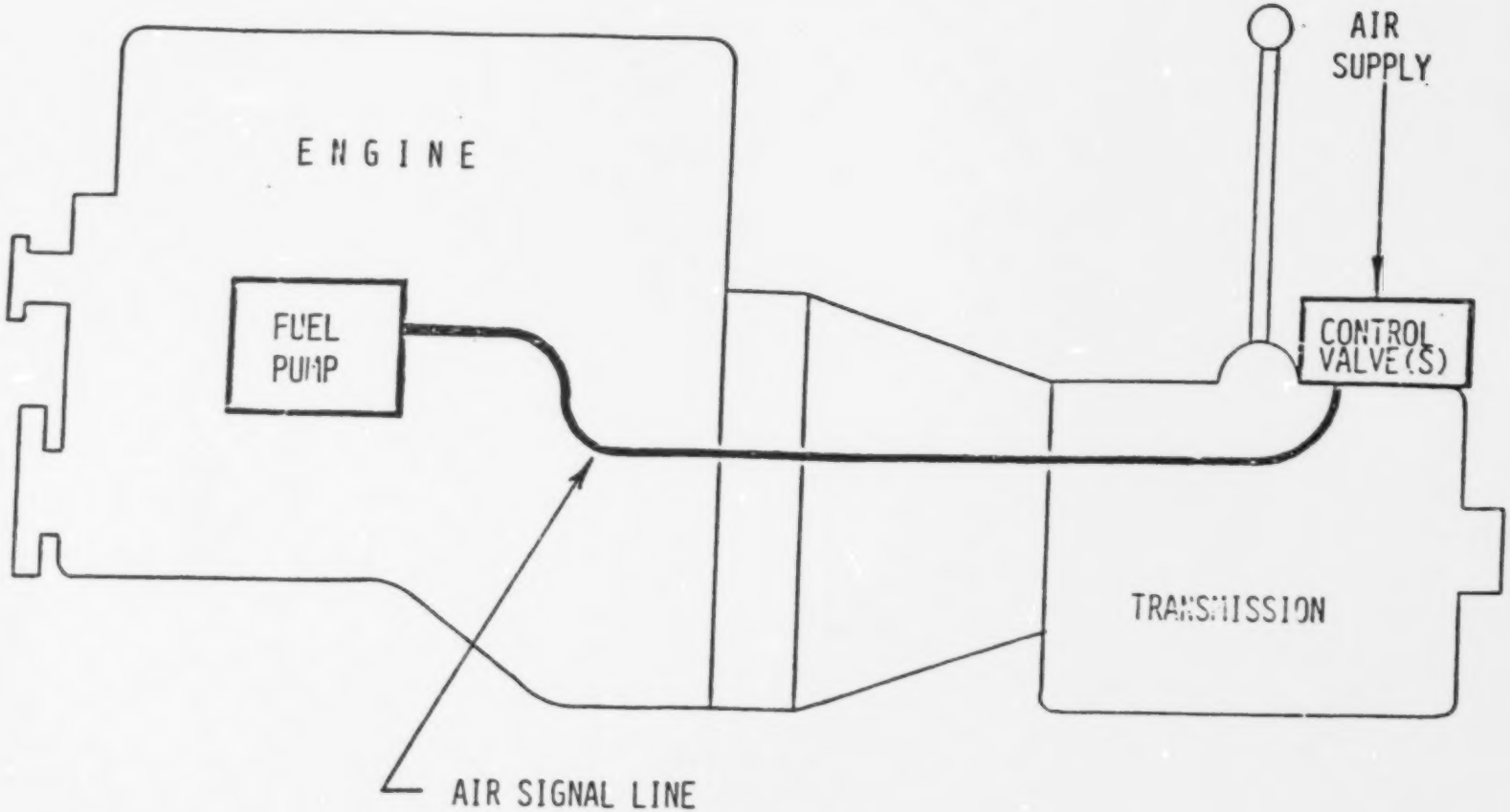
14. Start truck, build up air pressure and check all connections for air leaks.

15. When transmission is in tenth gear, high range, there should be no air to the governor. If there is, recheck procedures #7, #11 and #12.



CUMMINS ROAD SPEED GOVERNOR

SYSTEM SCHEMATIC

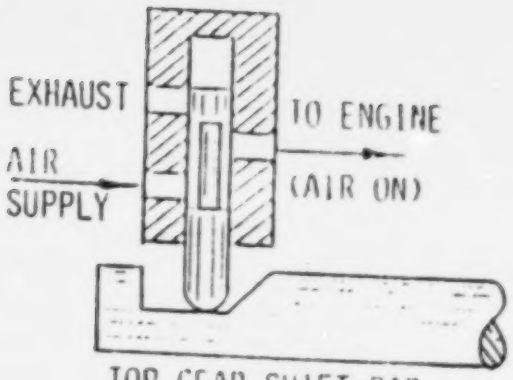


- AIR ON - FULL RATED SPEED
- AIR OFF - REDUCED ENGINE SPEED

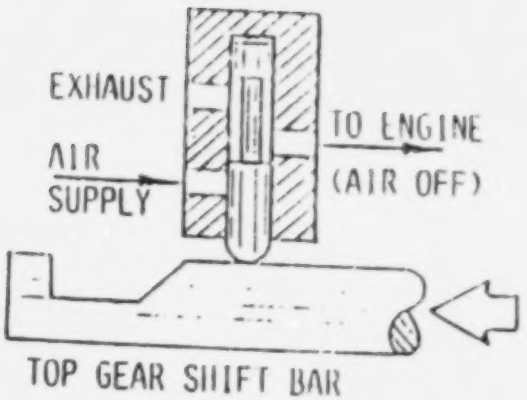
CUMMINS ROAD SPEED GOVERNOR

SIGNAL SYSTEM

ANY GEAR
EXCEPT
TOP GEAR

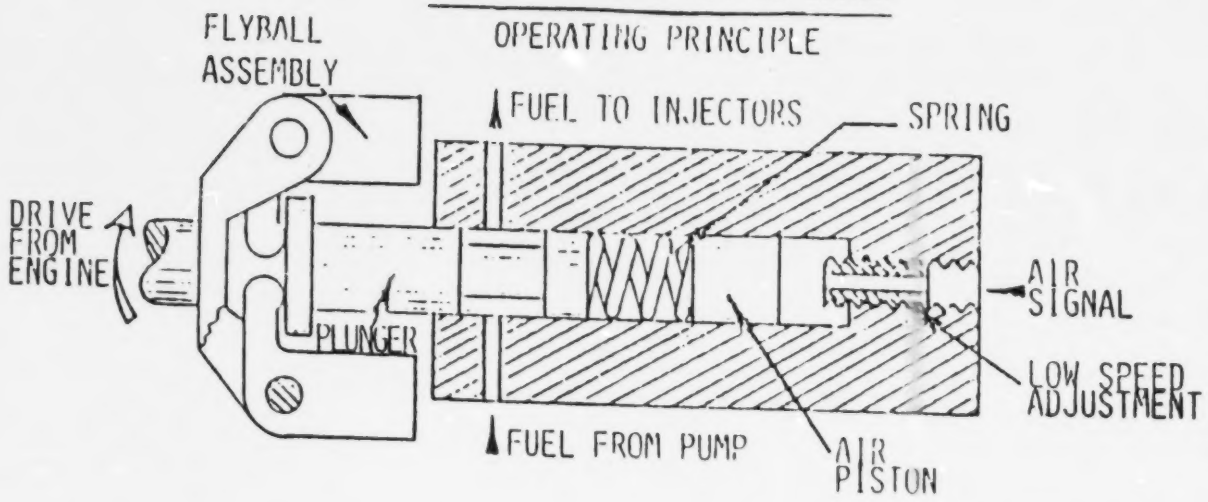


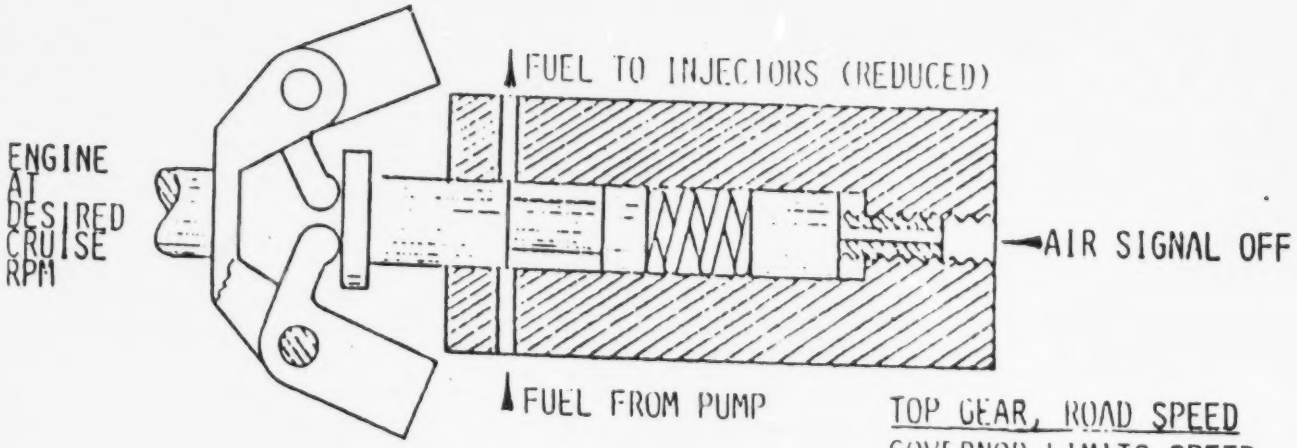
TOP GEAR



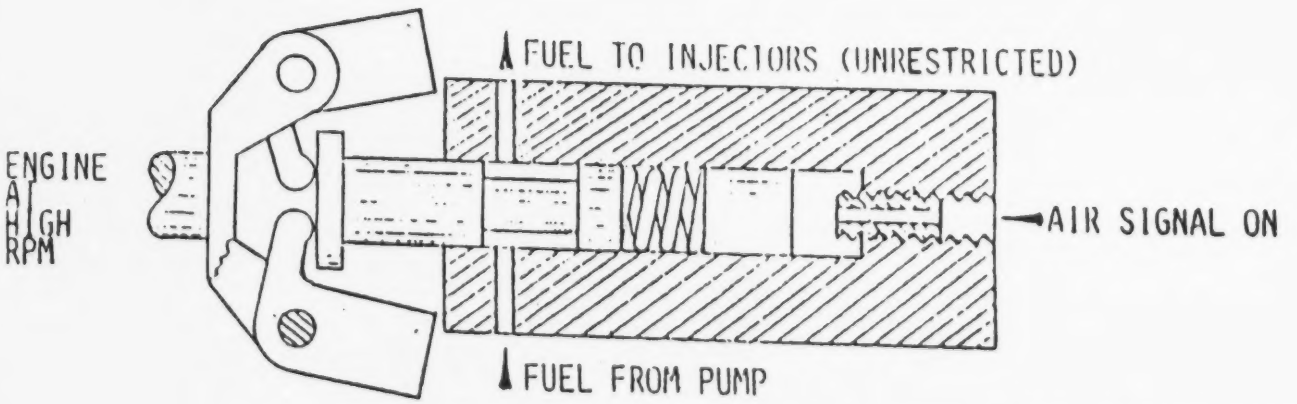
CUMMINS ROAD SPEED GOVERNOR

OPERATING PRINCIPLE





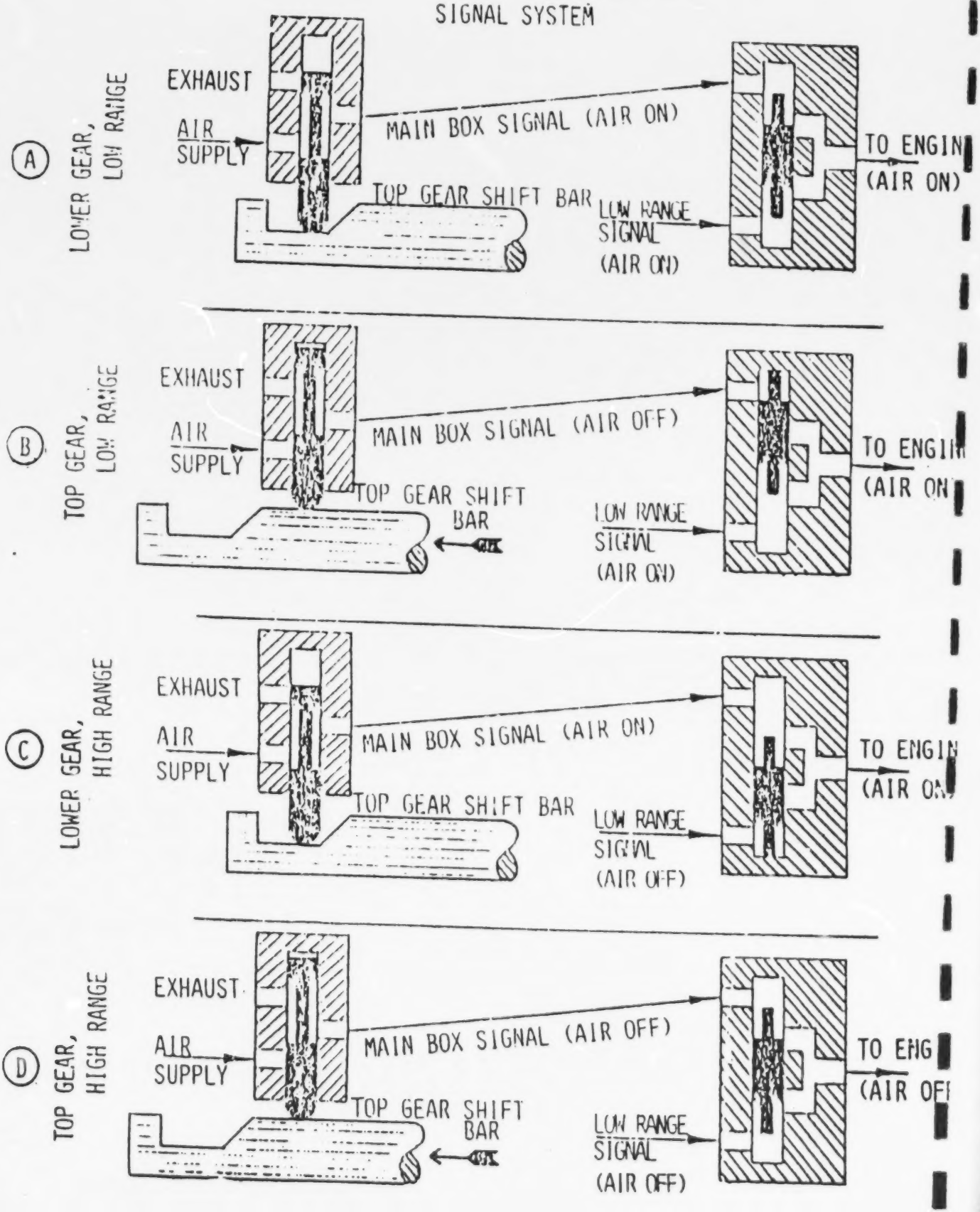
TOP GEAR, ROAD SPEED GOVERNOR LIMITS SPEED



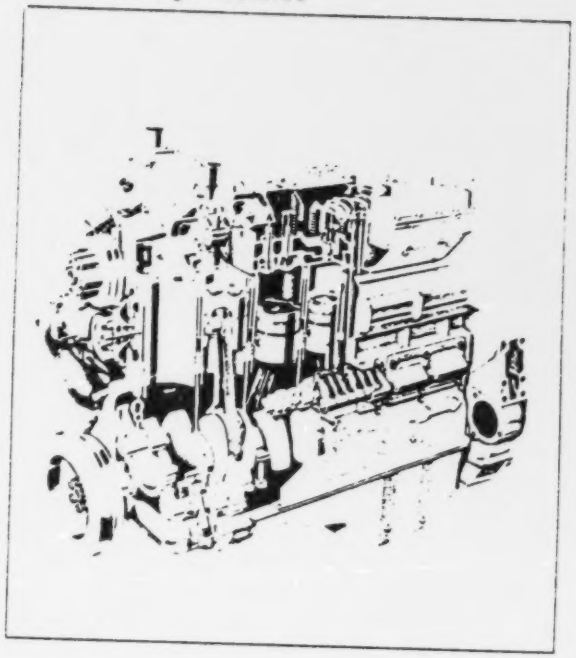
LOWER GEAR, ENGINE HIGH SPEED GOVERNOR LIMITS SPEE

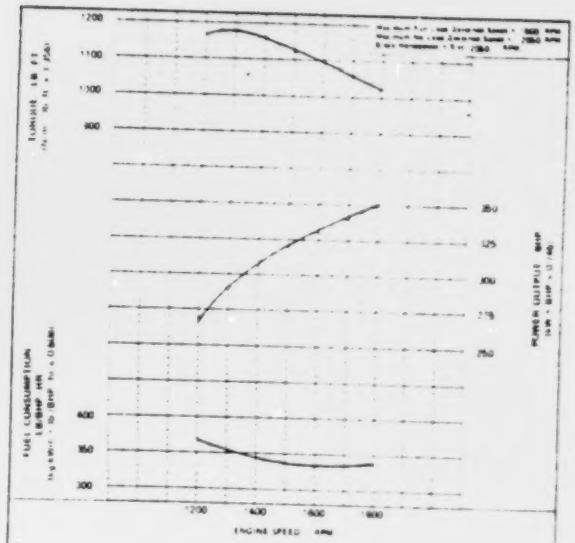
CUMMINS ROAD SPEED GOVERNOR

SIGNAL SYSTEM



Internal Design Features





Performance Curve: C-4121-A

CPL Code: 0530

Available Equipment

Air Compressor: Cummins 13.2 CFM (374 L/min.) one cylinder, coupling driven and pressure charged; 30 CFM (850 L/min.) two cylinder.

Corrosion Resistor: Spin-on type, mounted. Checks rust and corrosion, controls acidity, and removes impurities from coolant.

Electrical Equipment: 12 and 24 volt starter; 12 and 24 volt alternators of various ampere outputs.

Fan Mounting: Bracket mounted hub and pulley. Hub 20¼ in. (514 mm) above crankshaft.

Filters: Lubricating oil, spin-on paper element, full flow, and by-pass, engine mounted in combination with oil cooler, and oil pan. Fuel, spin-on paper element, engine mounted.

Flywheel: For 14 in. (356 mm) and 15½ in. (394 mm) 2 plate clutches to fit various automotive clutches.

Flywheel Housing: S.A.E. No. 1 or 2 cast aluminum with mounting pads.

Front Mounting: Provision for pad type engine support, or 6 in. (152 mm) diameter trunnion.

Governor: Automotive type or variable speed, dual flyweight with single or dual throttle controls.

Oil Pan: Stamped steel rear sump, cast aluminum front sump, 9 U.S. gallon (34.0 L) capacity.

Other Optional Accessories: Can be provided by Cummins upon request to fit special applications.

Steering Pump Drive: Coupling driven, two bolt flange mounting.

Thermostat: Single unit, modulating by-pass type; zero leak rate, can be used with shutterless cooling system.

Performance

Engine performance at SAE standard J816b conditions of 500 ft. (150 m) altitude (29.00 inches [736 mm] Hg dry barometer), 85°F (29°C) air intake temperature, and 0.38 inches (9.6 mm) Hg water vapor pressure with No. 2 diesel fuel will be within 5% of that shown at the time of engine shipment. Actual performance may vary with different ambient conditions.

Curves represent performance of the engine with water pump, lubricating oil pump, fuel system, compressor (unloaded) and air cleaner; not included are alternator, fan and optional equipment.

Conversion Factors to Metric:

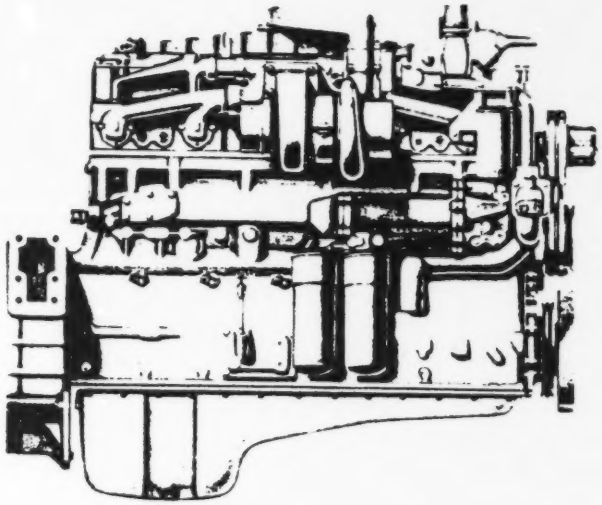
Torque	lb.-ft	x 1.356 =	_____	N•m
Power	bhp	x .746 =	_____	kW
Fuel	lb./bhp-hr	x .608 =	_____	kg/kW-hr.

Cummins has always been a pioneer in product improvement. Thus specifications may change without notice. Illustrations may include optional equipment.

Cummins Engine Company, Inc., Columbus, Indiana 47201

Automotive Diesel

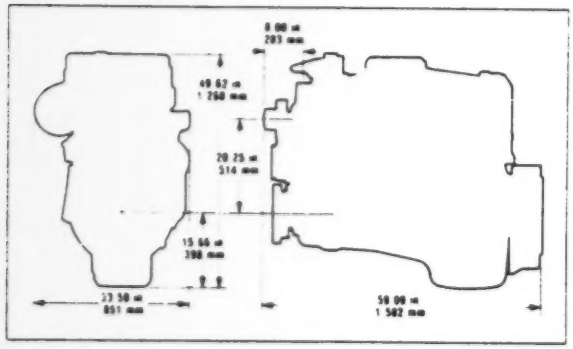
Formula® 350



Specifications

		Metric
Power Rating	350 bhp	261 kW
Rated Speed	1800 rpm	1800 rpm
Peak Torque (1300 RPM)	1175 lb.-ft.	1 593 N•m
Nominal Torque Rise	15%	15%
Clutch Engagement Torque (800 RPM)	625 lb.-ft.	848 N•m
Number of Cylinders	6	6
Bore and Stroke	5½ x 6 in.	140 x 152 mm
Piston Displacement	855 cu. in.	14 L
Compression Ratio	14.5:1	14.5:1
Operating Cycles	4	4
†Lube System Oil Cap.	11.0 U.S. gals.	42 L
Coolant Capacity	5.5 U.S. gals.	21 L
Net Weight with Std. Accessories, Dry	2520 lbs.	1 144 kg
Weight at Rated Power	7.2 lbs./hp	4.4 kg/kW
Installation Diagram Number		3032536

†Bypass filter is included in total.



Design Features

Camshaft: Large 2½ in. (64 mm) diameter camshaft controls all valve and injector movement. Induction hardened alloy steel with gear drive. Roller type camshaft followers for long cam and follower life.

Connecting Rods: Drop forged, 12 in. (305 mm) center to center length. Rifle drilled for pressure lubrication of piston pin. Taper piston pin end reduces bearing pressures.

Crankshaft: High tensile strength steel forging. Bearing journals and fillets are induction hardened. Fully counterweighted.

Cylinder Block: Alloy cast iron with removable, wet liners.

Cylinder Heads: Each head serves two cylinders. Drilled fuel supply and return lines. High temperature and wear resistant inserts on exhaust valve seats.

Exhaust Manifold: Pulse type design for less restricted and more energy efficient exhaust flow to the turbocharger.

Fuel System: Cummins PT™ wear-compensating system with integral governor. Camshaft actuated Top Stop injectors.

Intake Manifold: Includes integral air-to-water aftercooler for improved fuel consumption and emissions.

Lubricating Oil Cooler: Tube and fin type, two pass water cooled with spin-on full flow and by-pass filters. Temperature controlled by-pass circuit to maintain oil temperature. Integral pressure relief valve and low oil pressure/full flow filter restriction alarm.

Lubrication: Force feed to all bearings, gear type pump with pressure regulation from main bearing oil supply galley.

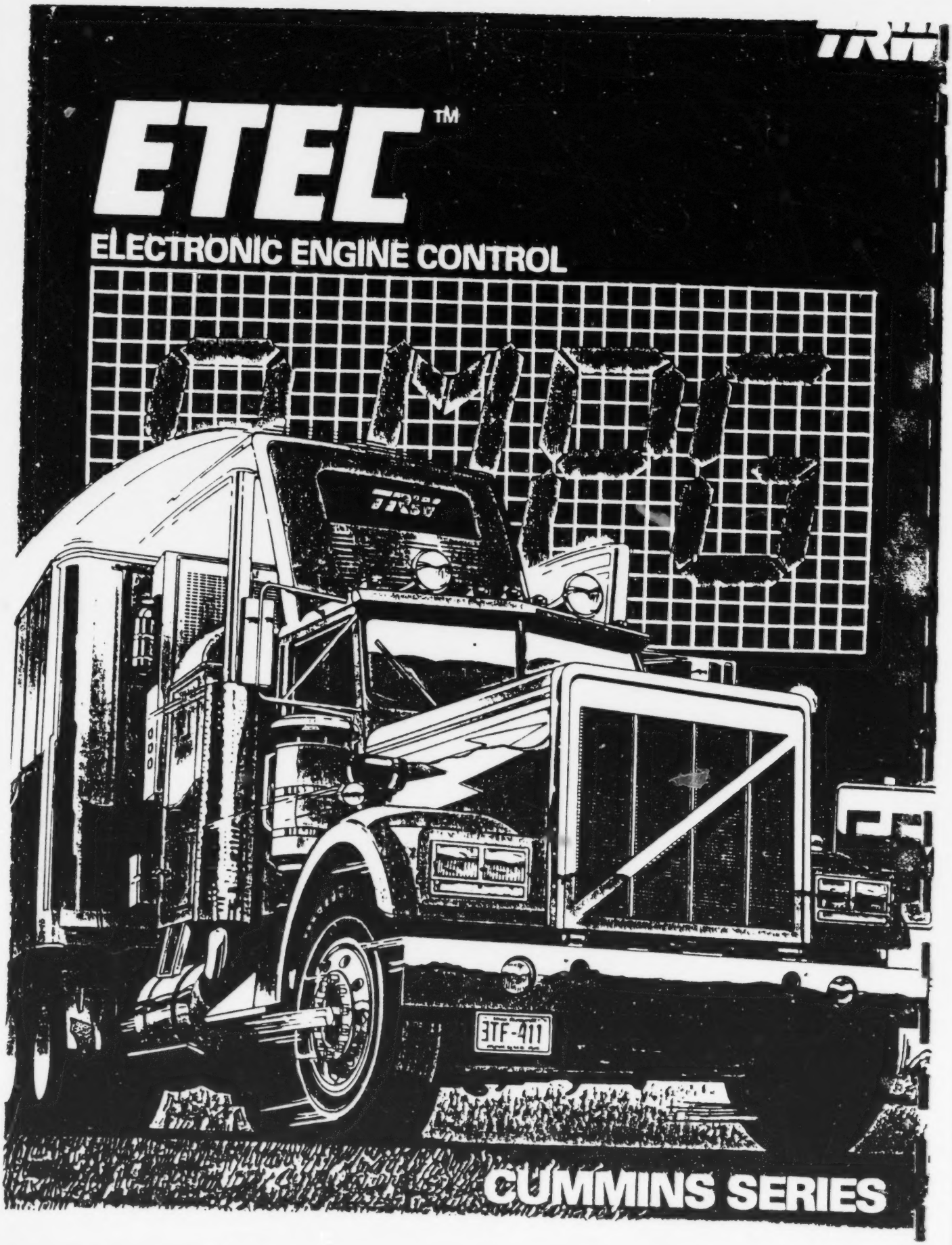
Turbocharger: Cummins manufactured T-468.

Valves: Dual intake and exhaust each cylinder. Each valve 1⅞ in. (47 mm) diameter. High temperature and wear resistant face on exhaust valve.

Water Pump: Reduced flow poly-vee belt driven, centrifugal type, with volute type housing cast in block.

APPENDIX C

DETAILS ON THE TRW ELECTRONIC TRUCK ENGINE CONTROL
(COMPANY LITERATURE)

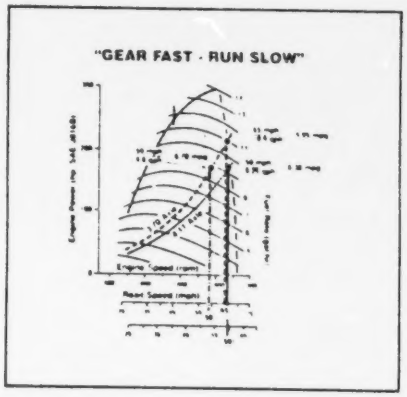

TRW
ETEC™
ELECTRONIC ENGINE CONTROL
3TF-411
CUMMINS SERIES

ETEC™...

NOT JUST ANOTHER GOVERNING SYSTEM, BUT...REPORTED FUEL SAVINGS UP TO 12 PERCENT AND MORE. A TOTAL CONTROL SYSTEM FROM A COMPANY CALLED TRW.

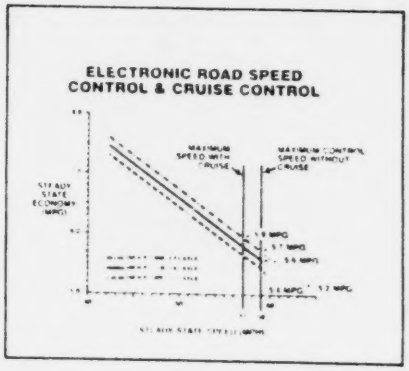
FLEET OWNERS' REPORT ON ETEC: SIGNIFICANT FUEL SAVINGS... REDUCED MAINTENANCE... IMPROVED DRIVER EFFICIENCY.

Vehicles equipped with ETEC have logged millions of miles in a wide variety of vocational applications. The RESULT: significant FUEL SAVINGS. The consumption charts shown here present the results of two studies — fuel savings up to 12 percent. Other reports are even more dramatic.



ETEC provides genuine driver comfort and lessens driver fatigue. Drivers like the smooth operation that ETEC provides — progressive shifting, minimal cab pulsation, the ability to drive with their hands instead of their feet.

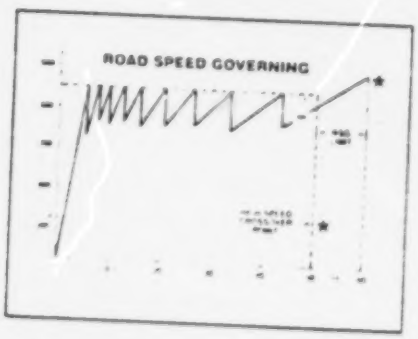
ETEC's built-in tamper-resistant features discourage attempts to defeat the system.



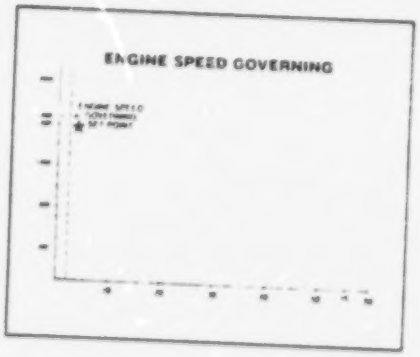
The chart above indicates typical fuel savings reported by maintenance executives using ETEC. These executives also report that troubleshooting is simple using the diagnostic unit designed to service the system.

UNLIKE CONVENTIONAL GOVERNING SYSTEMS, ETEC PROVIDES A COMBINATION OF GOVERNING FEATURES, OPTIMIZING FUEL SAVINGS IN ALL MODES OF OPERATION.

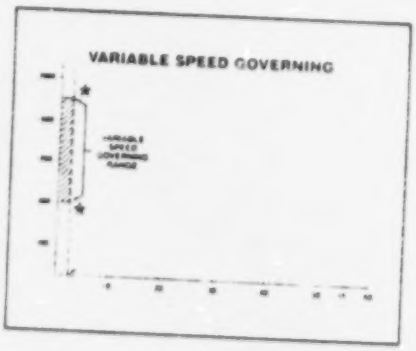
The system precisely controls the vehicle's ROAD SPEED to established limits. These specified limits* are programmed into the ETEC calibration module.



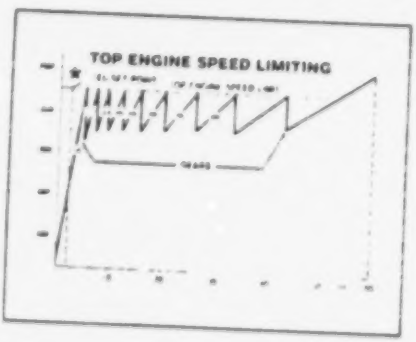
In the ENGINE SPEED GOVERNING mode, the ETEC System prevents costly overrevving of the engine and deters tampering with the speed sensors



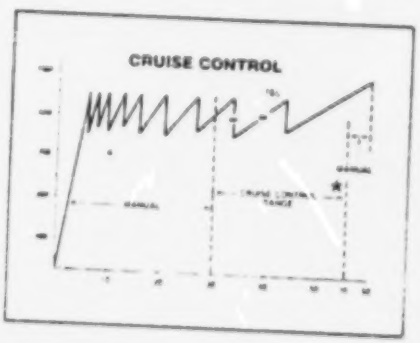
The VARIABLE SPEED GOVERNOR mode allows vehicle operators to vary engine RPM for vehicles with power takeoff equipment.



The TOP ENGINE LIMITER feature of ETEC limits engine speed through all of the gears, encouraging the operator to use the highest, most fuel-efficient gear at all times.



CRUISE CONTROL is an added feature of the ETEC System. But ETEC is more than just another Cruise Control or governing system — it is a complete vehicle/engine speed management system.



ETEC is an ELECTRONIC system, with all of the accuracy and reliability offered by electronics. The degree of automation offered by ETEC has won wide acceptance among fleet owners and operators alike. And, most of all, ETEC has been proven — proven to be fuel-efficient, proven to be reliable, proven to be easy to operate and provide driver comfort.

**Customer designates the set points.*

TRW

FROM A COMPANY CALLED TRW...TOMORROW'S HEAVY-DUTY TECHNOLOGY...QUALITY...RELIABILITY... FOR TODAY'S TRANSPORTATION.

Headquartered in Cleveland, Ohio, TRW is a worldwide company with more than 3,000 locations, providing research, design, engineering and manufacturing excellence to many markets. Transportation is one of the chief markets. TRW is the

only major industrial company combining mechanical, hydraulic, electrohydraulic and electronic expertise to the transportation industry.

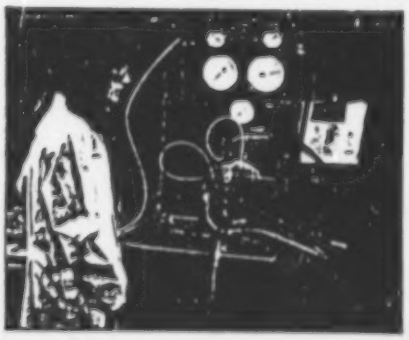
From our Transportation Electronics Division in Farmington, Michigan, we supply technologically advanced, cost-effective, products for the heavy-duty market. Picking the appropriate technologies for the heavy-duty market is a unique strength of TRW.

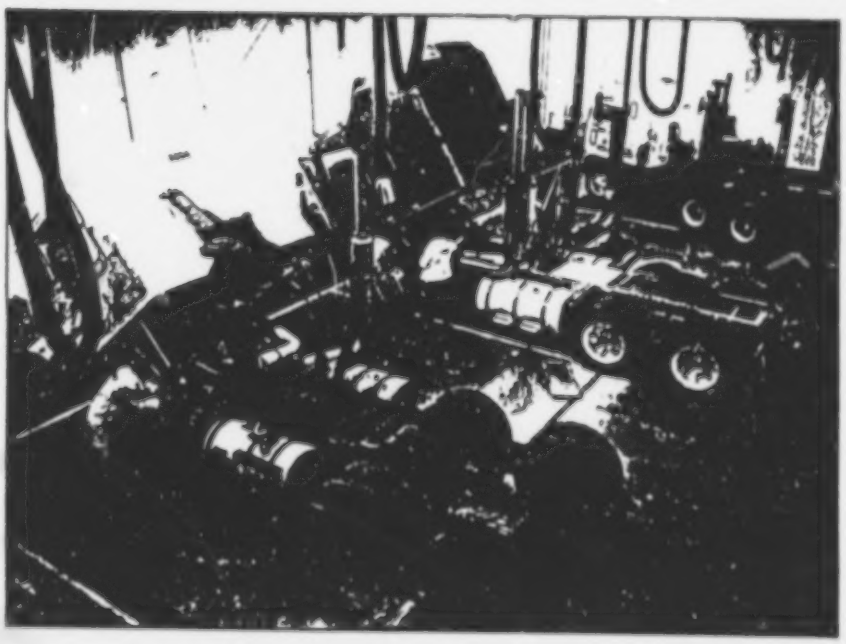
ETEC is custom-designed to perform its control functions with a specific application in mind — the *heavy-duty truck* application.

Using components proven to be reliable in heavy-duty truck applications, the ETEC System is manufactured under strict quality-control standards.

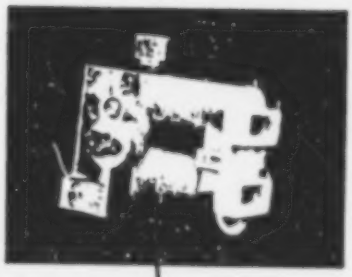
Quality control and testing procedures assure that each ETEC System will perform in the truck and on the road.

We perform stringent thermal-shock, vibration, dynamometer and additional quality assurance tests on ETEC before the system goes into service.



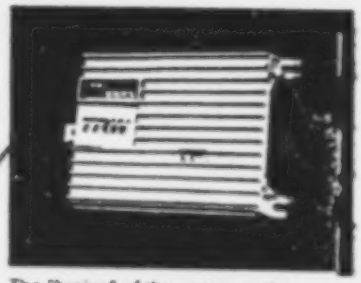


ETEC COMPONENTS...RESPONSIVE, ACCURATE, RELIABLE

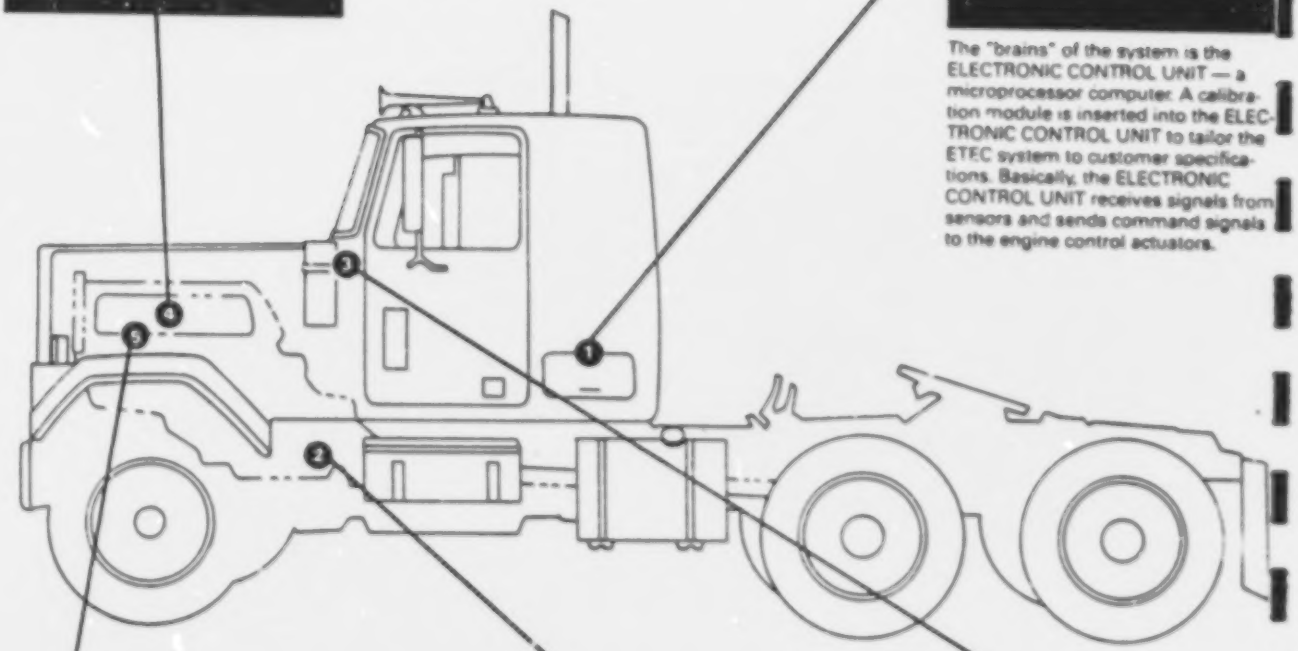


The FUEL CONTROL VALVE, the "heart" of the ETEC system precisely controls rail pressure and, thus, controls both engine speed and vehicle speed to 99 percent accuracy.

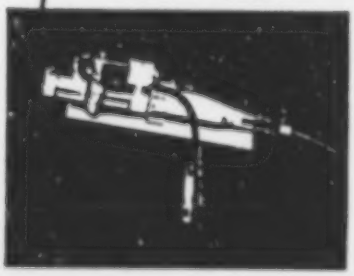
Command signals are received by the FUEL CONTROL VALVE from the Electronic Control Unit which compares input signals with the set points in the calibration module.

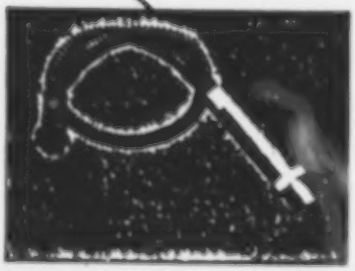


The "brains" of the system is the ELECTRONIC CONTROL UNIT — a microprocessor computer. A calibration module is inserted into the ELECTRONIC CONTROL UNIT to tailor the ETEC system to customer specifications. Basically, the ELECTRONIC CONTROL UNIT receives signals from sensors and sends command signals to the engine control actuators.



During the Cruise Control and variable speed governing modes of operation, the THROTTLE ACTUATOR holds the throttle open, thus allowing the Fuel Control Valve to control speed.





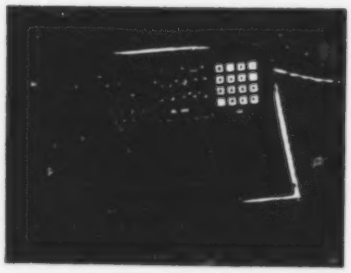
One input signal device is the ENGINE SPEED SENSOR which reads the engine RPM and transmits the speed signal to the Electronic Control Unit.

A second input device, the ELECTRONIC SPEED COUPLER, reads the road speed of the vehicle and sends the speed data to the Electronic Control Unit.

WARRANTY

TRW is pleased, proud and confident with ETEC. ETEC'S performance and durability are backed with a 1 year or 100,000 mile warranty.

SERVICE AND PARTS



TRW's Transportation Electronics Division has a well-trained staff of field service representatives, which in combination with our ETEC DIAGNOSTIC MODULE, assures our customers quick and quality service nationwide.

Service parts are readily available through our nationwide parts distribution system. TRW assures delivery of replacement parts within 24 hours of notice, keeping downtime to a minimum.

AVAILABILITY AND INSTALLATION

ETEC is currently available for Cummins engines. If your trucks are powered by Cummins, ETEC offers fuel savings, reduced maintenance and downtime, and added driver comfort and convenience.

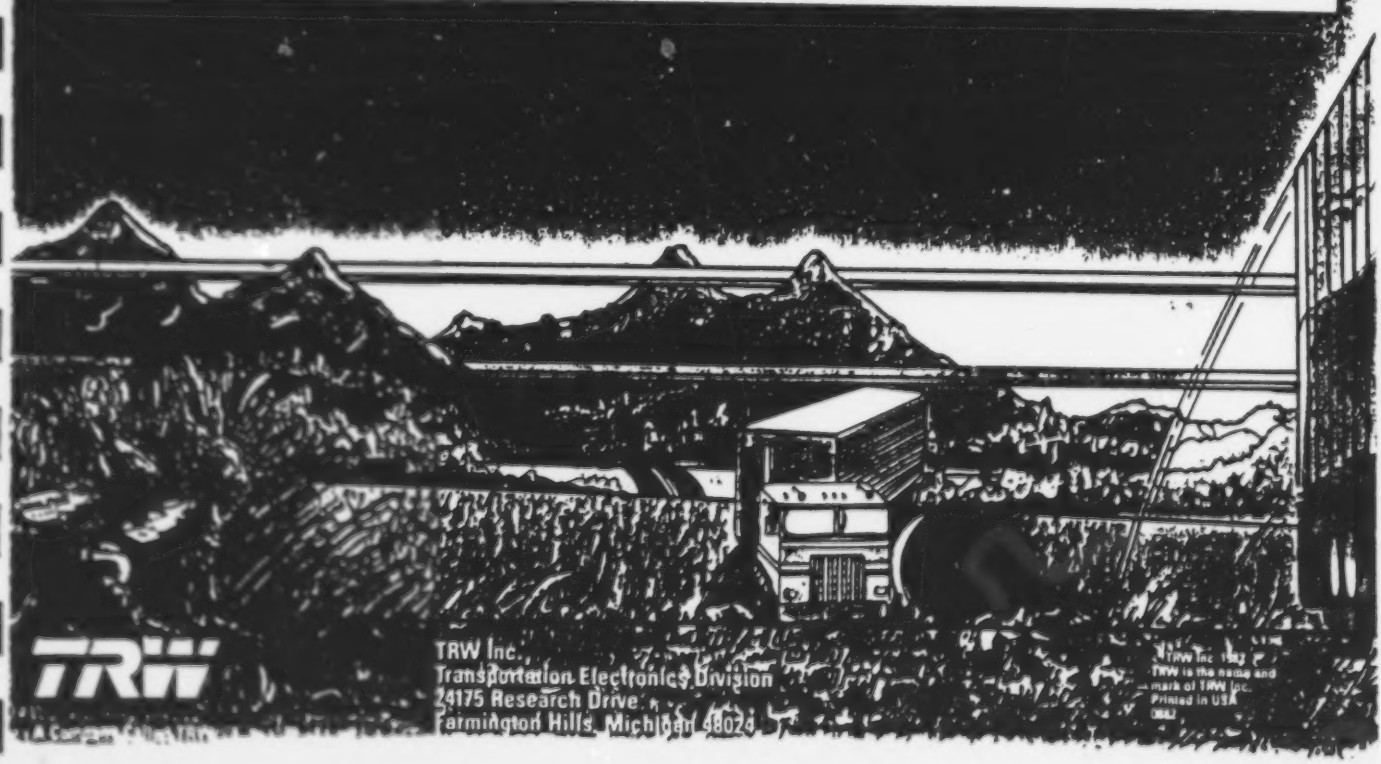
ETEC can be installed on a new vehicle or it can be easily retrofitted through TRW's Starter Kit program or by a TRW-approved distributor.

ETEC will soon be available for other engines as part of an entire electronic product line to serve the truck and bus industry . . .

IF YOU WANT TO OPTIMIZE FUEL ECONOMY FOR YOUR VEHICLES, DON'T LOCK YOURSELF INTO A FUEL MANAGEMENT SYSTEM UNTIL YOU'VE TALKED TO THE TRANSPORTATION PEOPLE AT . . . TRW, TRANSPORTATION ELECTRONICS DIVISION, 24175 RESEARCH DRIVE, FARMINGTON HILLS, MICHIGAN 48024, TELEPHONE (313) 478-7210.

TRW

ETEC



TRW

TRW Inc.
Transportation Electronics Division
24175 Research Drive
Farmington Hills, Michigan 48024

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Printed in USA

Driver's Handbook

TRW

The ETEC System

ELECTRONIC ENGINE AND CRUISE CONTROL FOR HEAVY-DUTY VEHICLES

Better driving, easier driving without sacrificing performance.

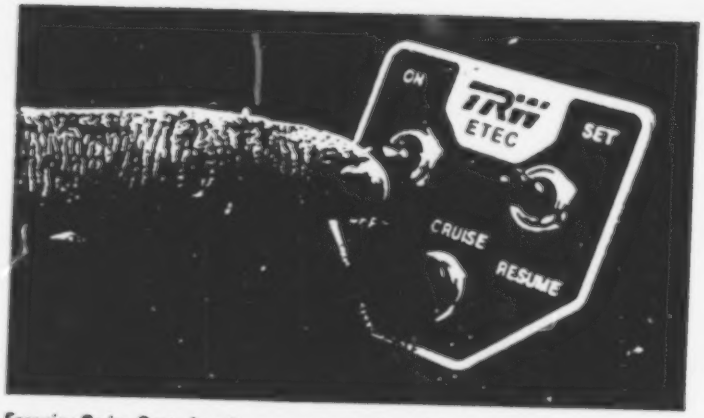
The ETEC System was specifically designed to do two things reduce fuel and maintenance costs, and make your driving job easier. Unlike mechanical governors or other limiters, the ETEC System does not sacrifice performance to gain increased econ omy. Nor does it rob you of your driving freedom. What it does do is help you operate your truck within its best performance range for the most comfortable, efficient and safest driving.

How it works. The ETEC System uses a microprocessor con trol module – actually a small on-board computer – to monitor and evaluate a number of different engine functions. The computer receives its information, such as road and engine speed, from sensing components of the ETEC System within the truck. It then automatically adjusts and maintains each function within predetermined settings while you drive.

Most of the time, you won't even have to operate the system. It automatically helps you get the most engine performance and economy as you drive.

The ETEC system is always in one of five operating functions. Two of them – Cruise Control and Variable Speed Governing – you have direct control over, the other three operate automat ically when either of the first two are not engaged. The five system functions are:

1. Cruise Control
2. Variable Speed Governing
3. Engine Speed Management
4. Top Engine Speed Monitoring
5. Road Speed Sensing



Engaging Cruise Control on the operator control panel.

1 Cruise Control

Cruise Control helps make your job easy. It is activated by the ON/OFF and SET/RESUME switches on the operator control panel, which is usually mounted on the right hand side of the dash within easy reach.

To cruise at a particular speed:

1 Flip the switch to ON.
2 Hold the throttle down until the speedometer indicates the desired speed.
3 Then momentarily depress the SET/RESUME switch to SET.

Instantly, the ETEC System locks in on your current speed which it will maintain until disengaged. You can then sit back, give your feet a rest, and let your hands do the driving.

If the truck starts pulling hills, the ETEC System will precisely increase fuel needs to maintain the chosen speed. When descending hills, the ETEC System will reduce fuel, automatically, to prevent over-revving and to maintain the selected road speed.

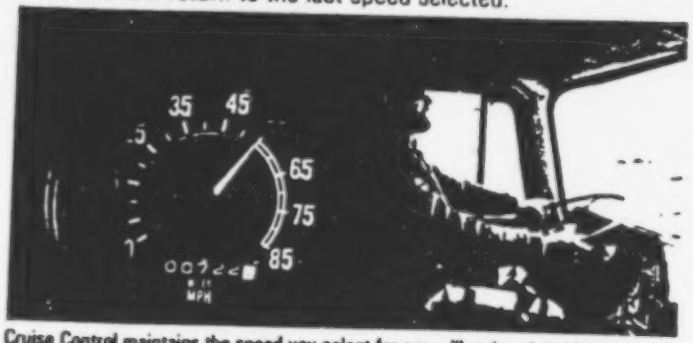
With cruise control, you can also accelerate or decelerate by momentarily holding down the SET/RESUME switch in either the SET or RESUME positions.

To deactivate the cruise control:

1 Apply the foot brake, trailer brake, or clutch pedal
2 Flip the ON/OFF switch to OFF

To resume preselected cruise speed:

1 Switch the ON/OFF switch to ON
2 Momentarily depress the SET/RESUME switch to RESUME. Cruise will return to the last speed selected.



Cruise Control maintains the speed you select for easy, "hands only" driving.

2 Variable Speed Governing

The variable speed governing function is used primarily to support power take-off operations. It has upper and lower limits, selected in 10 RPM increments, and is typically set between 800 and 1200 RPM or to maximum power take-off requirements. Normally, this function is used when the vehicle is stationary. It is engaged by activating the operator control panel ON/OFF and SET/RESUME switches. The engine speed can be trimmed up or down within the preselected limits with the SET/RESUME switch.

The Variable Speed Governing function is cancelled when:

1 The foot brake, trailer brake, or clutch pedal is depressed,
2 The ON/OFF switch is set in the OFF position, or
3 The vehicle's ignition switch is turned to an OFF or ACCESSORY position.

The variable engine speed function will also precisely hold RPMs above idle at an efficient level for warming up the engine and for air conditioning or heater operation even for extended periods of time without over revving the engine

3 Engine Speed Management

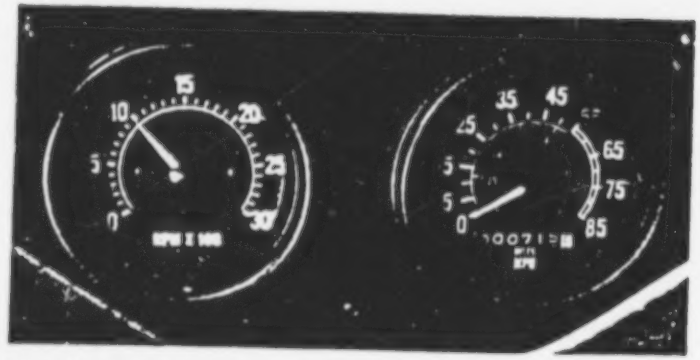
Engine speed management is a single point maximum limit that prevents over revving and accidental engine damage It will always be the controlling limit on the engine while the vehicle is stationary unless you are operating the vehicle in the variable speed governing function

The ETEC System works with drivers of all types of rigs to achieve up to 12% better fuel economy

4 Top Engine Speed Monitoring

The ETEC System's top engine speed monitoring functions aids progressive shifting through all the gears It works to maintain the most efficient RPM levels to reduce engine wear, lower engine noise, and save fuel

This function is pre set and is generally set at or below the engine's rated RPM limit It will always be in effect in all but the highest gear or when cruise control has been engaged It works to eliminate over revving and insure smoother, easier shifting for maximum fuel economy



Top engine speed monitoring helps you keep within the best RPM range needed for top fuel economy.

For example

1 Starting out in first gear, the engine accelerates to the pre set top engine speed Once reached, you shift to the next higher gear

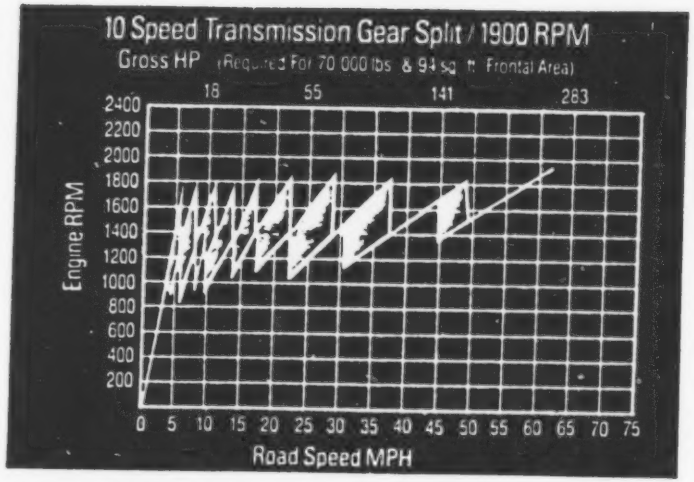
2 The engine again accelerates to top RPM limit and again you select the next highest gear

3 This continues throughout the shift pattern until top gear and desired road speed are reached

Running in high gear at reduced RPMs can save as much as one half to one gallon of fuel per hour as compared with the same speed in the next lower gear You save time, wear, and money without any extra work

The chart on the following page shows the difference between a standard shift pattern and the ETEC System's progressive shifting technique

The top line indicates the standard shift technique, the lower, progressive shifting The area between the two lines represents fuel savings



5 Top Road Speed Sensing

The ETEC System also has a top road speed sensing function which operates once the vehicle is in highest gear. It is a single-point maximum vehicle speed which is pre-set to TRW customer specifications. This function controls top road speed when the cruise control isn't engaged. The top road speed function gives you a choice. Because it is typically set at a higher speed than cruise control, you can choose to have the comfort of pedal-free driving, or, cancel the cruise control to run at a higher - though less efficient - speed.

The ETEC™ System from TRW... Keeping pace with the demands of the professional driver.

The ETEC System helps keep America's trucks on the highway with:

- Fuel Savings
- Reduced Maintenance and Downtime
- Added Driver Comfort and Convenience

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820907

Truck Electronic Engine Controls

Jerry R. Blevins and John J. Stephan
TRW Inc.

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Truck Electronic Engine Controls

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ABSTRACT

ELECTRONICS can control the engine combustion cycle by altering the fuel metering systems and/or fuel injection timing of Heavy Duty Trucks.

Precision control based on the particular engine fuel injection requirements may be adapted to specific combustion criteria. Driver performance, however, under certain conditions, can be the most influential fuel economy factor.

The driver performance element and an electronic control system to optimize that element is discussed.

After a two year actual inservice test conducted jointly by the Department of Transportation and SAE, it was concluded that a 21.1% difference in fuel economy could exist, dependant upon how a heavy-duty vehicle was driven.

Factors contributing to this significant fuel economy difference were:

- Use of reserve horsepower for increased road speed or faster acceleration rates over legal or necessary requirements.
- Improper application of power throughout the gear shift range.
- Highway cruising in a lower gear by using RPM's available in the droop range of the mechanical governor to achieve adequate road speed.

The driver of a vehicle today requires a device which can help him to command fuel economy rather than improperly use the reserve horsepower available. The vehicle owner requires a means to insure that the vehicle will be operated as required by the vehicle drivetrain components. This is based on certain maximum road speeds, average cruise speeds and defined gear operation.

In early 1982, TRW introduced an Electronic Truck Engine Control, ETEC, which was designed to address the following performance requirements:

- Precise control of vehicle speed and engine speed
- Maximum mileage at specified parameters
- Elimination of the droop associated with conventional governing systems
- Tamper-resistant

Unlike conventional governing systems, ETEC provides a combination of governing modes:

- Road speed governing which limits maximum vehicle speed
- Engine speed governing which limits maximum engine speed
- Variable speed governing for vehicles equipped with power takeoff equipment
- Top engine speed limiting which governs top engine speed through all of the gears to encourage the driver to use the highest practical gear
- Cruise Control, which enhances fuel savings and reduces driver fatigue

These ETEC operating modes are shown graphically in Figure 1. Operating parameters in this figure are represented by typical values. However, different parameters may be specified according to the user's needs.

The following paragraphs describe in more detail each of these modes.

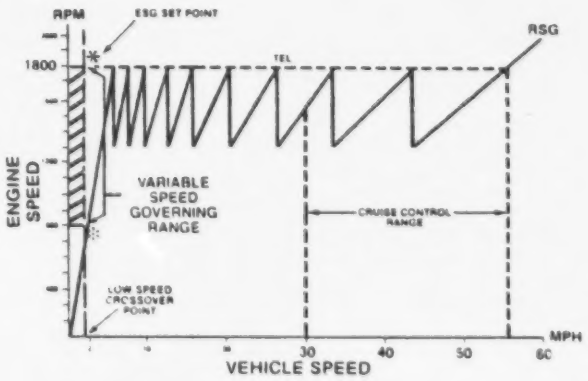

Fig. 1 ETEC Operating Modes

OPERATING MODES

ENGINE SPEED GOVERNOR (ESG) - Figure 2 depicts the ESG mode. This is a single-point speed limit and is in effect when the vehicle is stationary. When the vehicle moves above the low-speed crossover point, about two miles per hour, ESG is automatically cancelled. The ESG is actually a tamper-resistance feature. As can be seen from Figure 2, if 1650 RPM is the ESG limit, vehicle speed would be limited to about fifty miles per hour

in the highest gear. If a driver were to tamper with the vehicle speed sensor so that it did not sense actual road speed, the system would respond by limiting road speed to fifty miles per hour.

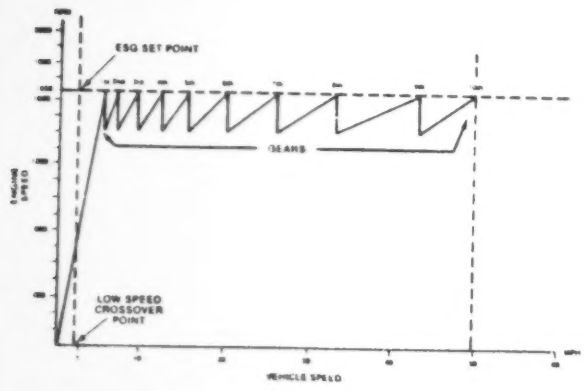

Fig. 2 Engine Speed Governor Mode

VARIABLE SPEED GOVERNOR (VSG) - VSG also is in effect only when the vehicle is stationary or at very low speed. In the application shown in Figure 3, VSG ranges from 800 to 1800 RPM. VSG is used primarily for power takeoff operations such as pumping, asphalt unloading, auxillary power generation or salt spreading.

The operator selects the desired RPM by accelerating the engine to the desired speed and setting that speed by activating the SET switch on the operator control module. Holding the SET switch in allows the operator to accelerate engine speed. Holding the RESUME switch in allows him to decelerate. The RESUME switch also allows the operator to return to the previously selected speed.

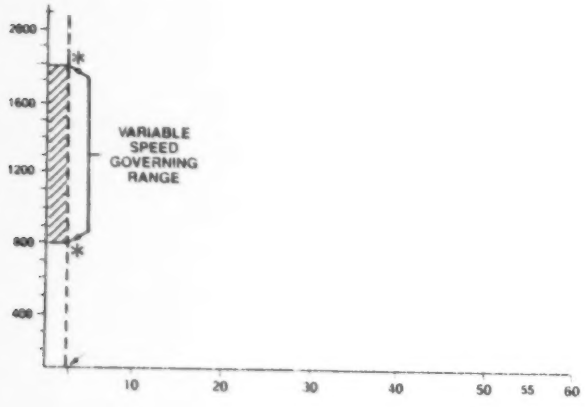

Fig 3 Variable Speed Governor Mode

TOP ENGINE SPEED LIMIT (TEL) - TEL is in effect whenever the vehicle is moving at a speed below a high-speed crossover point. By establishing the TEL at 1800 RPM as shown in Figure 4, the driver is encouraged to shift to top gear in order to exceed fifty miles per hour.

The TEL mode of operation saves fuel and reduces engine stress by reducing engine RPM resulting from operation in the droop range of the engine's mechanical governor during low vehicle speed and shifting operations.

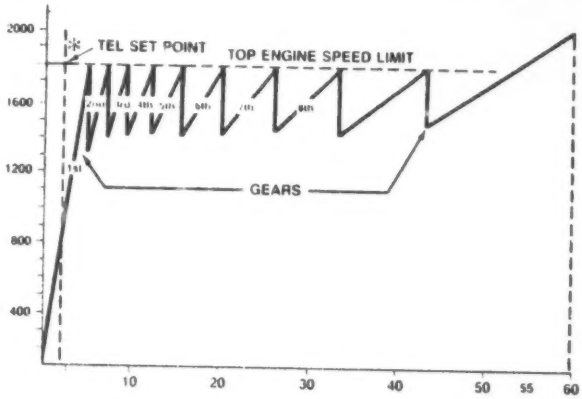

Fig 4 Top Engine Speed Limit Mode

ROAD SPEED GOVERNOR (RSG) - RSG or road speed governing is in effect at speeds above a high-speed crossover point. In Figure 5, the RSG range is between fifty miles per hour and the maximum limit of sixty miles per hour.

Note that the high-speed crossover point from the TEL mode to the RSG mode occurs after the vehicle is in the top gear. This crossover point is based on the vehicle's drivetrain configuration.

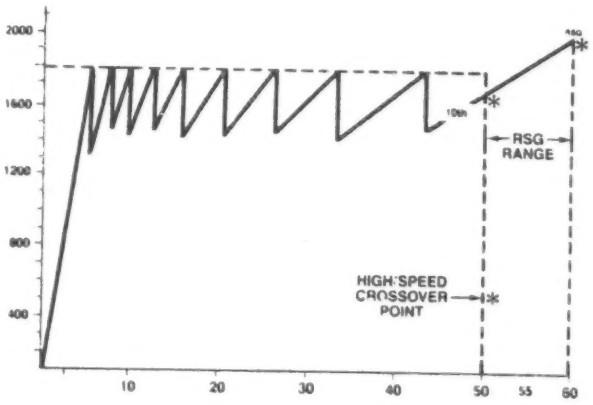

Fig. 5 Road Speed Governor Mode

CRUISE CONTROL - The Cruise Control mode is illustrated in Figure 6. In this example, it can be selected at any road speed between thirty and fifty-five miles per hour.

Cruise Control, like VSG, is activated by the driver pressing the SET switch or, if the speed has been previously set, the RESUME switch. It is deactivated by pressing the OFF switch or by stepping on the clutch or brake.

The driver can also accelerate by holding in the SET switch and decelerate by holding in the RESUME switch. Also, Cruise Control encourages drivers to drive in cruise at a lower speed than allowed in the RSG mode.

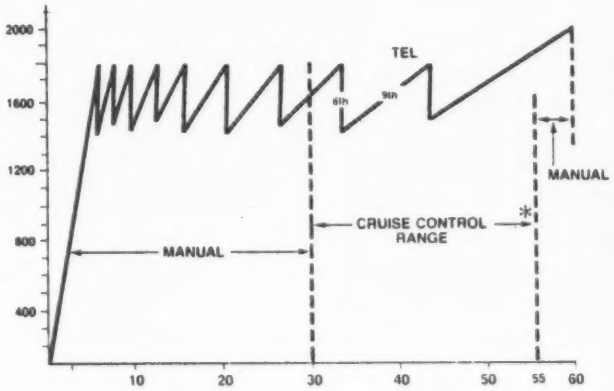

Fig 6. Cruise Control Mode

SYSTEM DESCRIPTION

The major components of the ETEC System are illustrated in Figure 7. Additional details on each of these components are presented in the following paragraphs.

VEHICLE SPEED SENSOR - Two types of vehicle speed sensors are utilized. The electronic road speed sensor normally used in conjunction with an existing electronic speedometer is usually mounted in the right rear wheel and generates a frequency proportional to the speed of the truck. The ETEC system interfaces with it through an auxillary electronic circuit which provides both filtering and isolation for the signal.

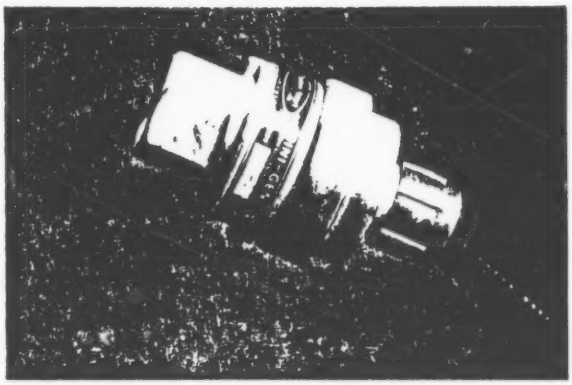

Fig. 8 Vehicle Speed Sensor

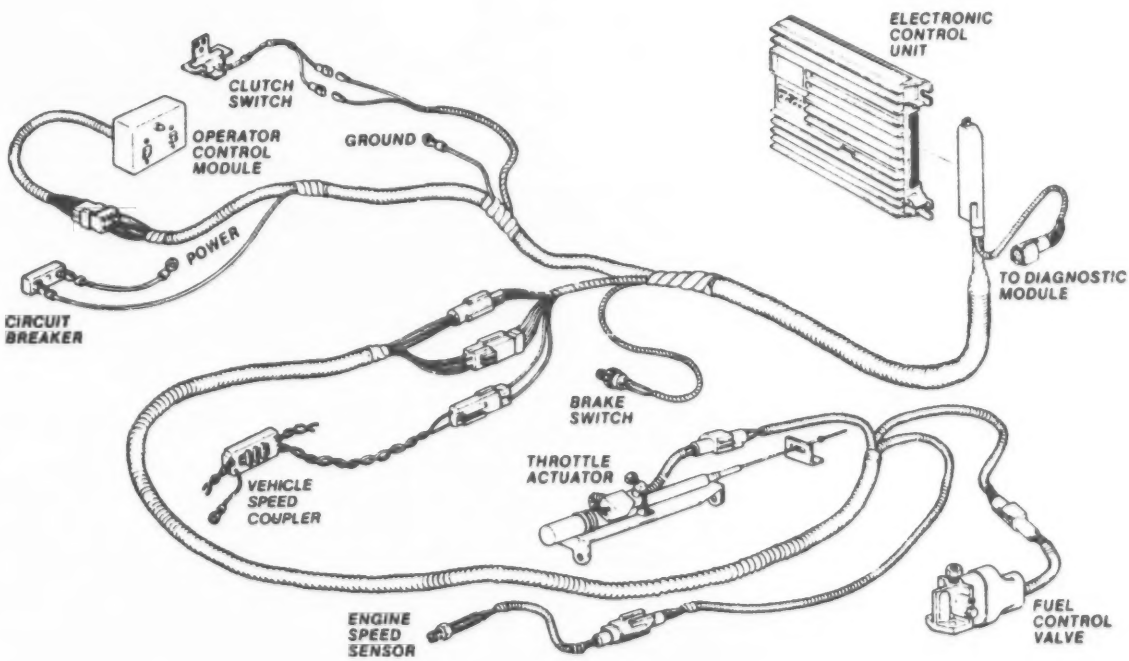

Fig. 7 ETEC System Components

The mechanical road speed sensor shown in Figure 8 is mounted on the transmissions of vehicles that have mechanical speedometers. A sinusoidal signal with a frequency proportional to vehicle speed is generated by this device and transmitted directly to the control module.

ENGINE SPEED SENSOR - Engine speed is sensed using a variable reluctance transducer, illustrated in Figure 9. This transducer is mounted in the engine bell housing in close proximity to the flywheel starter gear teeth. An AC signal with a frequency proportional to engine speed is generated by the motion of the gear teeth past the transducer and is transmitted to the control module.

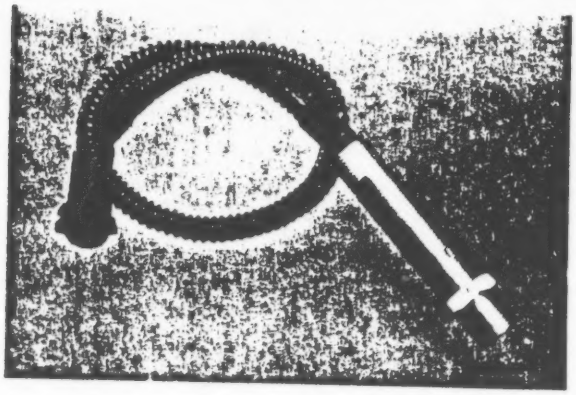

Fig. 9 Engine Speed Sensor

OPERATOR CONTROL - The Operator Control module, Figure 10, is mounted in the cab, usually at the driver's right. It contains the speed control On-Off and Set-Resume switches and a light which indicates when the VSG or Cruise modes are engaged.

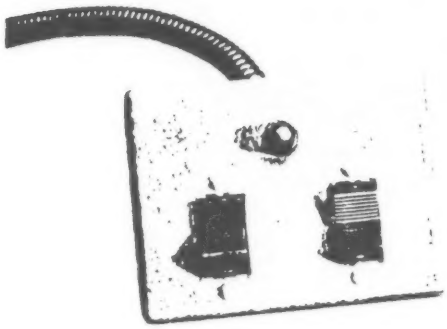

Fig. 10 Operator Control

SWITCHES - Two switches are provided to sense conditions for disengaging the cruise and variable speed functions. A mechanical limit switch detects motion of the clutch and a pneumatic switch detects activation of the air brakes. Both switches are configured and wired so that normal switch failure results in Cruise/VSG disengagement or inability to enter Cruise/VSG.

WIRING HARNESS - To both insure and control total system reliability, the ETEC system is complete with a heavy duty wiring harness that interconnects all of the system components. To improve durability it is shielded with hard flexible plastic conduit in critical areas, and terminated with connectors which mate with connectors on the other ETEC components.

ACTUATORS - Two actuators are provided in the system. The first actuator is a fuel control valve which limits the amount of fuel available to the engine by limiting fuel rail pressure in the event the driver attempts to exceed the preset engine or vehicle speed limit. As shown in Figure 11, the valve is installed on the output of the fuel pump in series with the fuel line to the injector rail. The valve reduces fuel rail pressure, keeping the speed in the desired operating range.

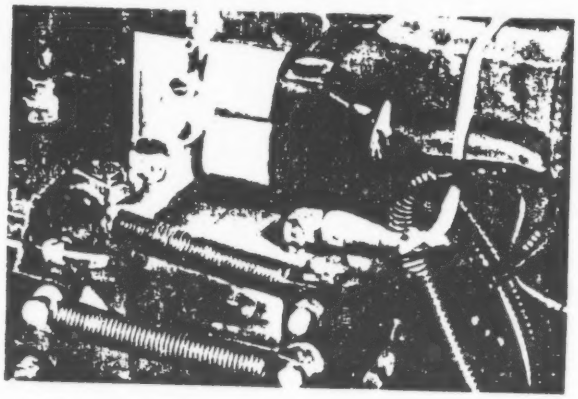

Fig. 11 Fuel Control Valve

For cruise control operations a second actuator is provided which holds the throttle in the wide open position. Once this is accomplished the fuel control actuator takes over to increase or decrease fuel flow according to load conditions. In the installation shown in Figure 12 the throttle actuator is mounted to the engine compressor with a linkage connected to the pump throttle lever.

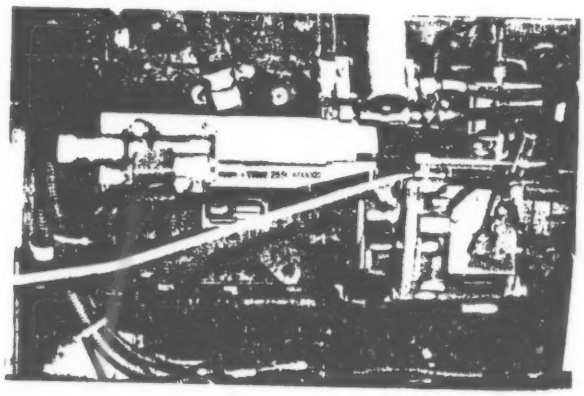

Fig. 12 Throttle Actuator

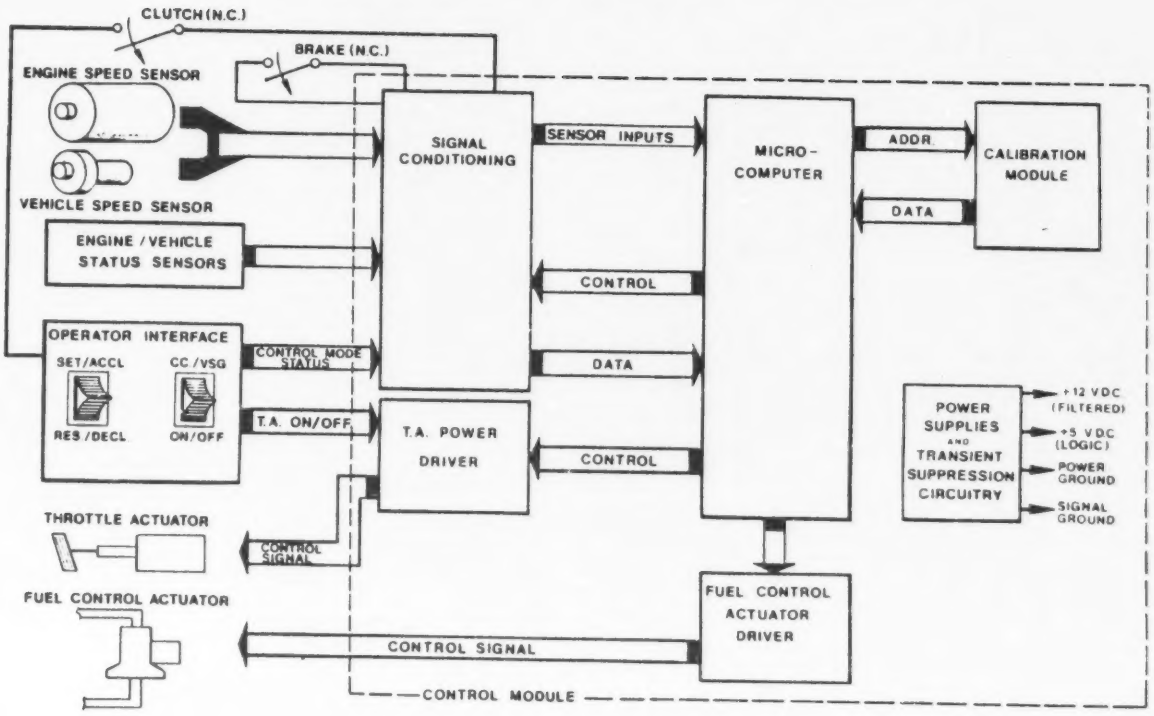

Fig. 13 Electronic Control Module and System Schematic

ELECTRONIC CONTROL MODULE - The control module is described in the schematic shown in Figure 13. The major components of the module are as follows: a microprocessor, which interprets sensor and command inputs and provides actuator control outputs; a memory module which calibrates the system for its particular vehicle application; power supply for the electronics; input signal conditioning and output power driver components; and internal self-check and fail-safe circuitry. As shown in Figure 14 these components are mounted in a cast aluminum housing designed to protect the electronics from the environment, dissipate the heat generated by the power drive components, and provide a shield against both received and transmitted electro-magnetic/electrostatic interference.

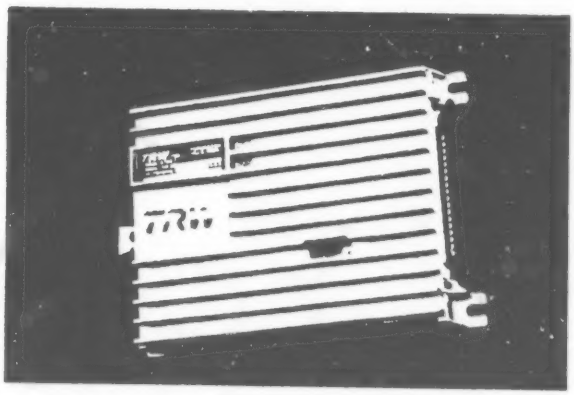

Fig. 14 Electronic Control Module

SYSTEM OPERATION

The fuel system for a typical Cummins 855 cu. in. engine with the ETEC control valve installed is shown in Figure 15. It can be seen that each of the controlling elements in the fuel pump can be regarded as a series of variable restrictions to fuel flow and the engine described as a fixed restriction.

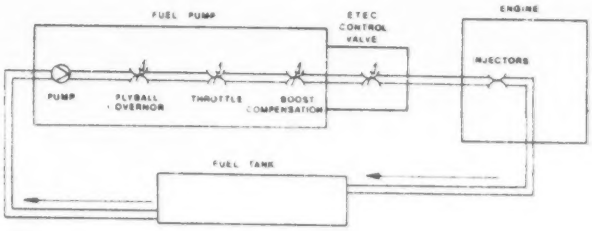

Fig. 15 Fuel System Schematic

The ETEC system controls the throttle restriction and places another variable restriction on the output of the pump. This allows the system to basically function on an auxillary single point electronic governor, with variable set points. In the limiting modes of ESG, RSG, and TEL, the set points are at the upper end of the engine and vehicle operating speeds. As long as the actual speeds are below the set points the proportional plus integral controller senses an error and commands the valve to open. In the fully open state, the valve does not restrict

engine operation. As the speed approaches and attempts to exceed the limits, the error decreases and changes sign, causing the valve to close and restrict fuel flow to a level required to maintain the limit speed. Once the speed drops below the limit, the error once again changes sign causing the valve to open, lessening and eventually eliminating the valve's restriction to fuel flow.

For the Cruise and VSG modes, the set point is adjusted by the driver within the allowable range. However, the throttle actuator is energized causing the conventional throttle to be held wide open. The control system, using the valve, regulates fuel flow in response to the relationship between the actual speed and the set point. Depressing the brake, clutch, or turning the control switch off, disengages the Cruise and VSG functions and returns the control system to the appropriate limiting mode.

SYSTEM PERFORMANCE

The function of the ETEC System is to increase vehicle operating efficiency. This is accomplished by electronically limiting vehicle and engine speeds while also providing increased driver convenience with cruise control. The system provides an independent means of overriding the conventional engine governor, thus allowing the vehicle's drivetrain to be specified to maximize operating efficiency. To illustrate this principle, the performance of a typical vehicle with two drivetrain specifications is shown in Figure 16. Drivetrain A represents a vehicle gearing which allows the vehicle to be driven, under typical road load conditions in excess of the desired maximum speed, in this case 60 MPH. Drivetrain B represents gearing which, in combination with the engine governor, limits vehicle speed under the same load conditions to the desired speed. Point 2 on drivetrain B indicates a lower vehicle operating speed and lower fuel consumption but approximately the same engine operating speed as Point 1. Point 3, on the other hand, shows that the same vehicle operating speed is achieved as Point 2, but at a lower fuel consumption rate, resulting from increased engine loading at reduced RPM.

Utilizing cruise control at a speed slightly less than the maximum road speed, further fuel saving can be achieved, as illustrated by Point 4. Here again, vehicle speeds and therefore fuel consumption is reduced. Although fuel economy is a function of many variables other than road speed, computer simulation and field tests have demonstrated that fuel savings by the installation of the ETEC system and specifying the gear train accordingly will range between 5%-15%.

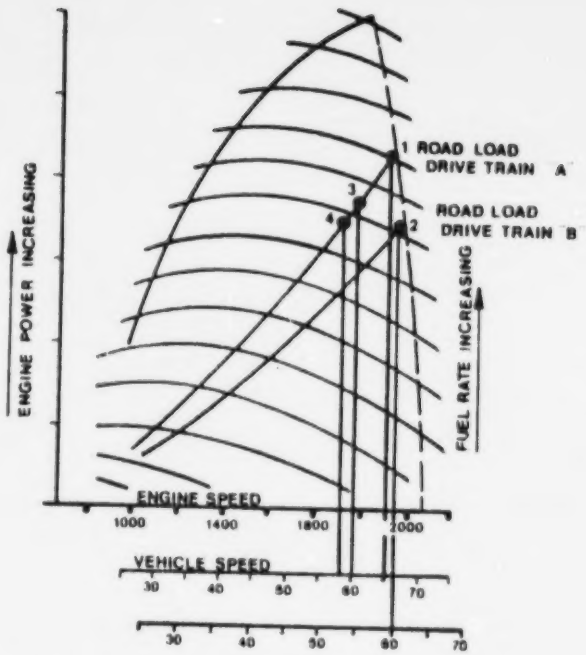

Fig. 16 System Performance

CONCLUSION

The primary benefit which electronic controls offer to the heavy duty truck application is that of system flexibility. This flexibility allows control of system criteria based on well defined modes of operation. Modes which are common to daily truck usage are:

- Road Speed Governing
- Engine Speed Governing
- Top Engine Speed Limiting
- Variable Speed Governing & Cruise Control

These modes must be addressed in a total governing system in order to maximize overall vehicle fuel economy and performance. Though these modes are primarily performance oriented, the fuel economy gains obtained are significant and are most cost effectively achieved through the use of electronics.

APPENDIX D

DETAILED STATISTICAL ANALYSIS
OF
TEST RESULTS

MILEAGE ANALYSIS

COMPARISON OF MILEAGE: BEFORE/AFTER MWAYS' BOTH TRUCKS

Variable under analysis - RAW MPG

Variable used to group cases - BEFORE/AFTER

Group 1 A/
A=AFTER

Number of cases	= 65
Mean	= 5.69
Variance	= 0.16
Standard deviation	= 0.40
Standard error of the mean	= 0.05

Group 2 B/
B=BEFORE

Number of cases	= 62
Mean	= 5.68
Variance	= 0.22
Standard deviation	= 0.47
Standard error of the mean	= 0.06

T-Test statistics

Difference (Mean X - Mean Y)	= 0.007
Standard error of the difference	= 0.079
t - statistic	= 0.086
Degrees of freedom	= 125
Probability of t (One tailed test)	= 0.464
Probability of t (Two tailed test)	= 0.929

Mann-Whitney U	= 1866.0
Two-tailed probability	= 0.472

MILEAGE ANALYSIS

COMPARISON OF MILEAGE: BEFORE/AFTER MWAYS' BOTH TRUCKS

Variable under analysis - CORRECTED MPG

Variable used to group cases - BEFORE/AFTER

Group 1 A/
A=AFTER

Number of cases	= 65
Mean	= 5.94
Variance	= 0.16
Standard deviation	= 0.40
Standard error of the mean	= 0.05

Group 2 B/
B=BEFORE

Number of cases	= 62
Mean	= 5.88
Variance	= 0.60
Standard deviation	= 0.77
Standard error of the mean	= 0.10

T-Test statistics

Difference (Mean X - Mean Y)	= 0.056
Standard error of the difference	= 0.110
t - statistic	= 0.510
Degrees of freedom	= 125
Probability of t (One tailed test)	= 0.309
Probability of t (Two tailed test)	= 0.617

Mann-Whitney U	= 1929.5
Two-tailed probability	= 0.680

MILEAGE ANALYSIS

COMPARISON OF MILEAGE: BEFORE/AFTER MWAYS' TRUCK 553974

Variable under analysis - RAW MPG

Variable used to group cases - BEFORE/AFTER

Group 1 A/
A=AFTER

Number of cases	= 25
Mean	= 5.84
Variance	= 0.14
Standard deviation	= 0.37
Standard error of the mean	= 0.08

Group 2 B/
B=BEFORE

Number of cases	= 30
Mean	= 5.76
Variance	= 0.31
Standard deviation	= 0.55
Standard error of the mean	= 0.10

T-Test statistics

Difference (Mean X - Mean Y)	= 0.086
Standard error of the difference	= 0.133
t - statistic	= 0.649
Degrees of freedom	= 53
Probability of t (One tailed test)	= 0.263
Probability of t (Two tailed test)	= 0.526

Mann-Whitney U	= 312.5
Two-tailed probability	= 0.291

MILEAGE ANALYSIS

COMPARISON OF MILEAGE: BEFORE/AFTER MWAYS' TRUCK 553974

Variable under analysis - CORRECTED MPG

Variable used to group cases - BEFORE/AFTER

Group 1 A/
A=AFTER

Number of cases	= 25
Mean	= 6.04
Variance	= 0.15
Standard deviation	= 0.39
Standard error of the mean	= 0.08

Group 2 B/
B=BEFORE

Number of cases	= 30
Mean	= 6.09
Variance	= 0.27
Standard deviation	= 0.52
Standard error of the mean	= 0.10

T-Test statistics

Difference (Mean X - Mean Y)	=-0.051
Standard error of the difference	= 0.128
t - statistic	= 0.401
Degrees of freedom	= 53
Probability of t (One tailed test)	= 0.346
Probability of t (Two tailed test)	= 0.692

Mann-Whitney U	= 375.5
Two-tailed probability	= 0.993

MILEAGE ANALYSIS

COMPARISON OF MILEAGE: BEFORE/AFTER MWAYS' TRUCK 553909

Variable under analysis - RAW MPG

Variable used to group cases - BEFORE/AFTER

Group 1 A/
A=AFTER

Number of cases	= 40
Mean	= 5.59
Variance	= 0.15
Standard deviation	= 0.39
Standard error of the mean	= 0.06

Group 2 B/
B=BEFORE

Number of cases	= 32
Mean	= 5.61
Variance	= 0.14
Standard deviation	= 0.37
Standard error of the mean	= 0.07

T-Test statistics

Difference (Mean X - Mean Y)	=-0.018
Standard error of the difference	= 0.091
t - statistic	= 0.199
Degrees of freedom	= 70
Probability of t (One tailed test)	= 0.419
Probability of t (Two tailed test)	= 0.837

Mann-Whitney U	= 640.0
Two-tailed probability	= 1.000

MILEAGE ANALYSIS

COMPARISON OF MILEAGE: BEFORE/AFTER MWAYS' TRUCK 553909

Variable under analysis - CORRECTED MPG

Variable used to group cases - BEFORE/AFTER

Group 1 A/
A=AFTER

Number of cases	= 40
Mean	= 5.87
Variance	= 0.16
Standard deviation	= 0.40
Standard error of the mean	= 0.06

Group 2 B/
B=BEFORE

Number of cases	= 32
Mean	= 5.68
Variance	= 0.82
Standard deviation	= 0.91
Standard error of the mean	= 0.16

T-Test statistics

Difference (Mean X - Mean Y)	= 0.189
Standard error of the difference	= 0.162
t - statistic	= 1.169
Degrees of freedom	= 70
Probability of t (One tailed test)	= 0.122
Probability of t (Two tailed test)	= 0.245

Mann-Whitney U	= 567.5
Two-tailed probability	= 0.411

MILEAGE ANALYSIS - GARDEWINE NORTH

COMPARISON OF MILEAGE: OLD & NEW CAT VS. CUMMINS

Variable under analysis - RAW MPG

Variable used to group cases - TRUCK TYPE

Group 1 A/B/
A=OLD CAT
B=NEW CAT

Number of cases	= 62
Mean	= 5.90
Variance	= 0.30
Standard deviation	= 0.54
Standard error of the mean	= 0.07

Group 2 C/
C=CUMMINS

Number of cases	= 76
Mean	= 5.87
Variance	= 0.28
Standard deviation	= 0.53
Standard error of the mean	= 0.06

T-Test statistics

Difference (Mean X - Mean Y)	= 0.026
Standard error of the difference	= 0.093
t - statistic	= 0.284
Degrees of freedom	= 136
Probability of t (One tailed test)	= 0.387
Probability of t (Two tailed test)	= 0.774

Mann-Whitney U = 2290.5
Two-tailed probability = 0.779

MILEAGE ANALYSIS - GARDEWINE NORTH

COMPARISON OF MILEAGE: OLD & NEW CAT VS. CUMMINS

Variable under analysis - CORRECTED MPG

Variable used to group cases - TRUCK TYPE

Group 1 A/B/
A=OLD CAT
B=NEW CAT

Number of cases	= 62
Mean	= 6.12
Variance	= 0.29
Standard deviation	= 0.53
Standard error of the mean	= 0.07

Group 2 C/
C=CUMMINS

Number of cases	= 76
Mean	= 6.09
Variance	= 0.29
Standard deviation	= 0.54
Standard error of the mean	= 0.06

T-Test statistics

Difference (Mean X - Mean Y)	= 0.032
Standard error of the difference	= 0.093
t - statistic	= 0.350
Degrees of freedom	= 136
Probability of t (One tailed test)	= 0.364
Probability of t (Two tailed test)	= 0.727

Mann-Whitney U	= 2247.5
Two-tailed probability	= 0.642

MILEAGE ANALYSIS - GARDEWINE NORTH

COMPARISON OF MILEAGE: OLDCAT VS. NEWCAT

Variable under analysis - RAW MPG

Variable used to group cases - TRUCK TYPE

Group 1 A/
A=OLD CAT

Number of cases	= 20
Mean	= 5.76
Variance	= 0.29
Standard deviation	= 0.54
Standard error of the mean	= 0.12

Group 2 B/
B=NEW CAT

Number of cases	= 42
Mean	= 5.97
Variance	= 0.29
Standard deviation	= 0.54
Standard error of the mean	= 0.08

T-Test statistics

Difference (Mean X - Mean Y)	=-0.202
Standard error of the difference	= 0.148
t - statistic	= 1.367
Degrees of freedom	= 60
Probability of t (One tailed test)	= 0.087
Probability of t (Two tailed test)	= 0.173

Mann-Whitney U	= 496.0
Two-tailed probability	= 0.252

MILEAGE ANALYSIS - GARDEWINE NORTH

COMPARISON OF MILEAGE: OLDCAT VS. NEWCAT

Variable under analysis - CORRECTED MPG

Variable used to group cases - TRUCK TYPE

Group 1 A/
A=OLD CAT

Number of cases	= 20
Mean	= 6.04
Variance	= 0.28
Standard deviation	= 0.53
Standard error of the mean	= 0.12

Group 2 B/
B=NEW CAT

Number of cases	= 42
Mean	= 6.16
Variance	= 0.28
Standard deviation	= 0.53
Standard error of the mean	= 0.08

T-Test statistics

Difference (Mean X - Mean Y)	=-0.127
Standard error of the difference	= 0.147
t - statistic	= 0.863
Degrees of freedom	= 60
Probability of t (One tailed test)	= 0.302
Probability of t (Two tailed test)	= 0.604

Mann-Whitney U	= 462.0
Two-tailed probability	= 0.527

MILEAGE ANALYSIS - GARDEWINE NORTH

COMPARISON OF MILEAGE - OREHAUL VS. LINEHAUL

Variable under analysis - RAW MPG

Variable used to group cases - TRUCK TYPE

Group 1 C/
C=LINEHAUL

Number of cases	= 76
Mean	= 5.87
Variance	= 0.28
Standard deviation	= 0.53
Standard error of the mean	= 0.06

Group 2 E/
E=ORE HAUL

Number of cases	= 116
Mean	= 4.99
Variance	= 0.22
Standard deviation	= 0.47
Standard error of the mean	= 0.04

T-Test statistics

Difference (Mean X - Mean Y)	= 0.889
Standard error of the difference	= 0.074
t - statistic	= 12.068
Degrees of freedom	= 190
Probability of t (One tailed test)	= 0.000
Probability of t (Two tailed test)	= 0.000

Mann-Whitney U	= 913.0
Two-tailed probability	= 0.000

MILEAGE ANALYSIS - GARDEWINE NORTH

COMPARISON OF MILEAGE - OREHAUL VS. LINEHAUL

Variable under analysis - CORRECTED MPG

Variable used to group cases - TRUCK TYPE

Group 1 C/

C=LINEHAUL

Number of cases	= 76
Mean	= 6.09
Variance	= 0.29
Standard deviation	= 0.54
Standard error of the mean	= 0.06

Group 2 E/
E=ORE HAUL

Number of cases	= 116
Mean	= 5.14
Variance	= 0.19
Standard deviation	= 0.44
Standard error of the mean	= 0.04

T-Test statistics

Difference (Mean X - Mean Y)	= 0.954
Standard error of the difference	= 0.071
t - statistic	= 13.365
Degrees of freedom	= 190
Probability of t (One tailed test)	= 0.000
Probability of t (Two tailed test)	= 0.000

Mann-Whitney U	= 727.0
Two-tailed probability	= 0.000

APPENDIX E

EXAMPLES OF EXPERIMENTAL PROCEDURES AND CONDITIONS AGREEMENTS AND VEHICLE SPECIFICATION SHEETS

EXPERIMENTAL PROCEDURES AND CONDITIONS

Carriers participating in the Manitoba Trucking Association truck fuel conservation device tests agree to observe the test procedures and conditions noted below:

1. Test routes, cargo weights and equipment type and age are to be representative of actual operations and fleet conditions.

2. Power units and trailers/bodies being tested are not to be used for other purposes or on other routes or modified in any way until the series of before and after tests are completed without notifying the consultant.

3. For long-haul highway routes (road speed governor), drivers are to be instructed not to idle trucks under any circumstances and to keep driving within urban areas to an absolute minimum.

4. Where applicable, tachograph cards are to be supplied to the consultant on a loan basis.

5. For urban pick-up and delivery operations (anti-idling device), test vehicles are to be assigned to routes which provide enough distance and time to consume a minimum of 30% of the tank capacity or a minimum of 6 gal. (22.7 l.) of fuel per day, whichever is greater.

6. To the extent controllable by the company, vehicles are to be operated according to vehicle, engine and transmission manufacturers' recommendations (engine speeds and shift points).

7. All vehicles are to be in proper operating condition as determined by the operator conducting the test at all times.

8. Drivers selected are to be sufficiently skilled so that the test results are not affected by the driver's technique improvement during the test period.

9. All vehicles tested within a company are to be in similar mechanical condition and be representative of the condition of vehicles in the fleet. All test vehicles are to undergo the operator's regular maintenance program whenever necessary at approximately the same time for all test and non-test vehicles operating in similar circumstances.

10. At the beginning of each daily anti-idling test cycle the vehicle is to be filled to the top every morning and the odometer reading recorded on the recording sheet to be provided. Vehicles not equipped with fuel flow meters should be equipped with gas cap locks. For vehicles equipped with fuel flow meters, "start cycle" and "stop cycle" fuel consumption is also to be recorded. Data is to be provided to the consultant at the end of each cycle or each day, whichever is longest.

11. Speedometers and odometers are to be checked for accuracy and proper working order before the series of tests are run.

12. The company will allow the participating drivers to be interviewed by the consultant after the tests to determine their views on the devices.

13. The company will participate in educating the trucking industry about the devices by allowing its experiences with the devices and truck fuel conservation in general to be made public in written and oral presentations by the Manitoba Trucking Association, E. M. LUDWICK & ASSOCIATES INC., Energy Mines and Resources Canada, Manitoba Energy and Mines and Manitoba Highways and Transportation.

We hereby agree to adhere to the above-mentioned conditions and procedures in participating in this project.

SIGNATURE OF AGREEMENT

_____	_____
Motor Carrier	for the Motor Carrier
_____	_____
Date	for E. M. LUDWICK & ASSOCIATES INC.

MANITOBA TRUCKING ASSOCIATION
25 Bunting Street, Winnipeg, Manitoba R2X 2P5
Telephone 632-6600

MTA TRUCK FUEL CONSERVATION DEVICE TEST
(Vehicle Identification)

COMPANY: Canadian Motorways OFFICER: J. Attenborrow

DEVICE: Cummins OEM RSG ROUTE: Winnipeg - Saskatoon

POWER UNIT

Unit Number	553974 and 553909	
Make	Ford	
Model	LT 9000	
Year	1984	
Number of Miles Recorded to Date	50 (new)	
Number of Axles	3	
Number of Drive Axles	2	
Engine Make/Model	Cummins Big Cam 3 Formula 350	
Rated Power (bhp)	350	hp(kw)
Peak Torque	1175 lb ft at 1300	RPM
Transmission Make/Model	Fuller RT 14615	
Differential Make/Model	Eaton	
Differential Ratio	3.70:1	
Tire Size/Type/Make/Model	Michelin 11R24.5	
Tire Pressure (Cold)	100	psi (kPa)
5th Wheel Setting (express in (mm) the distance 5th wheel fulcrum is ahead or behind the center line of bogie)	6"	in (mm)

TRAILER BODY

Unit Number	various	
Make	Fruehauf	
Model		
Year	1972-83	
Type (Van, Flatbed, Tank, etc.)	van	
Type of Side	ribbed	
Type of Corner	rounded	
Height	13' 2"	
Length	45'	
Tire Size/Type/Make/Model	11/ 24 /5 Bridgestone Radial	
Tire Pressure (Cold)	105	psi (kPa)
Number of Axles on Trailers(s)	2	
G.V.W. (Measured on Scale)	various	
Kingpin Setting	32	in (mm)
Cab-to-Trailer Gap	50	in (mm)

Date _____ Approved By: _____

MANITOBA TRUCKING ASSOCIATION
25 Bunting Street, Winnipeg, Manitoba R2X 2P5
Telephone 632-6600

MTA TRUCK FUEL CONSERVATION DEVICE TEST
(Vehicle Identification)

COMPANY: Gardewine North OFFICER: W. Francis

DEVICE: Cummins OEM RSG ROUTE: Winnipeg - North Man.

POWER UNIT

Unit Number		1090, 1091, 1092, 1093	
Make		Ford	
Model		LTL 9000	
Year		1984-85	
Number of Miles Recorded to Date		200,000 Miles	
Number of Axles		3	
Number of Drive Axles		2	
Engine Make/Model		Cummins Big Cam 3 Formula 350	
Rated Power (bhp)			hp(kw)
Peak Torque	1175	lb ft at 1300	RPM
Transmission Make/Model		Fuller RT 14615	
Differential Make/Model		EATON 400P	
Differential Ratio		3.70:1	
Tire Size/Type/Make/Model		11 x 22.5 Michelin	
Tire Pressure (Cold)		100	psi (kPa)
5th Wheel Setting (express in (mm) the distance 5th wheel fulcrum is ahead or behind the center line of bogie)		6" (152 mm)	in (mm)

TRAILER BODY

Unit Number	Various	
Make	Fruehauf	
Model		
Year	81-85	
Type (Van, Flatbed, Tank, etc.)	Vans or Flats	
Type of Side	Smooth	
Type of Corner	Curved	
Height	102"	
Length	45' or 48'	
Tire Size/Type/Make/Model	11/ 22 /5 Michelin radial	
Tire Pressure (Cold)	100	psi (kPa)
Number of Axles on Trailers(s)	2	
G.V.W. (Measured on Scale)	various	
Kingpin Setting	30"	in (mm)
Cab-to-Trailer Gap	60" to 72"	in (mm)

Date _____ Approved By: _____

MANITOBA TRUCKING ASSOCIATION
25 Bunting Street, Winnipeg, Manitoba R2X 2P5
Telephone 632-6600

MTA TRUCK FUEL CONSERVATION DEVICE TEST
(Vehicle Identification)

COMPANY: Gardewine North OFFICER: W. Francis

DEVICE: Preset Sealed Governor Screw ROUTE: Winnipeg - North Man.

POWER UNIT

Unit Number		2037	
Make		Kenworth	
Model		W900	
Year		1980	
Number of Miles Recorded to Date		180,000	
Number of Axles		3	
Number of Drive Axles		2	
Engine Make/Model		CAT 400	
Rated Power (bhp)		400	hp(kw)
Peak Torque	1265	lb ft at 1300	RPM
Transmission Make/Model		Fuller RT 12513	
Differential Make/Model		Rockwell 4000P	
Differential Ratio		4.44:1	
Tire Size/Type/Make/Model		11 x 22.5 Michelin	
Tire Pressure (Cold)		100	psi (kPa)
5th Wheel Setting (express in (mm) the distance 5th wheel fulcrum is ahead or behind the center line of bogie)		6" (152 mm)	in (mm)

MANITOBA TRUCKING ASSOCIATION
25 Bunting Street, Winnipeg, Manitoba R2X 2P5
Telephone 632-6600

MTA TRUCK FUEL CONSERVATION DEVICE TEST
(Vehicle Identification)

COMPANY: Gardewine North OFFICER: W. Francis

DEVICE: Preset Sealed Governor Screw (ESG) ROUTE: Winnipeg - North Man.

POWER UNIT

Unit Number		2028, 2023, 2052	
Make		Ford	
Model		LTL 9000	
Year		1984-85	
Number of Miles Recorded to Date		200,000	
Number of Axles		3	
Number of Drive Axles		2	
Engine Make/Model		CAT 3406B	
Rated Power (bhp)		350	hp(kw)
Peak Torque	1320	lb ft at 1200	RPM
Transmission Make/Model		Fuller RT 14615	
Differential Make/Model		Eaton 400P	
Differential Ratio		3.70:1	
Tire Size/Type/Make/Model		11 x 22.5 Michelin	
Tire Pressure (Cold)		100	psi (kPa)
5th Wheel Setting (express in (mm) the distance 5th wheel fulcrum is ahead or behind the center line of bogie)		6" (152mm)	in (mm)

MANITOBA TRUCKING ASSOCIATION
25 Bunting Street, Winnipeg, Manitoba R2X 2P5
Telephone 632-6600

MTA TRUCK FUEL CONSERVATION DEVICE TEST
(Vehicle Identification)

COMPANY: Gardewine North OFFICER: W. Francis

DEVICE: Preset Sealed Governor Screw (ESG) ROUTE: Winnipeg - North Man.

POWER UNIT

Unit Number		2036	
Make		Kenworth	
Model		W900	
Year		1980	
Number of Miles Recorded to Date		600,000	
Number of Axles		3	
Number of Drive Axles		2	
Engine Make/Model		CAT 380	
Rated Power (bhp)		380	hp(kw)
Peak Torque	1245 lb ft at 1200		RPM
Transmission Make/Model		Fuller RT012515	
Differential Make/Model		Rockwell 4000P	
Differential Ratio		4.11:1	
Tire Size/Type/Make/Model		11 x 22.5 Michelin	
Tire Pressure (Cold)		100	psi (kPa)
5th Wheel Setting (express in (mm) the distance 5th wheel fulcrum is ahead or behind the center line of bogie)		6" (152mm)	in (mm)

MANITOBA TRUCKING ASSOCIATION
25 Bunting Street, Winnipeg, Manitoba R2X 2P5
Telephone 632-6600

MTA TRUCK FUEL CONSERVATION DEVICE TEST
(Vehicle Identification)

COMPANY: Gardewine North OFFICER: W. Francis

DEVICE: Preset Sealed Governor Screw (ESG) ROUTE: Winnipeg - North Man.

POWER UNIT

Unit Number		2039	
Make		Ford	
Model		LT9000	
Year		1980	
Number of Miles Recorded to Date		350,000	
Number of Axles		3	
Number of Drive Axles		2	
Engine Make/Model		CAT 380	
Rated Power (bhp)		325	hp(kw)
Peak Torque	1245	lb ft at 1200	RPM
Transmission Make/Model		Fuller RT12515	
Differential Make/Model		Eaton 380	
Differential Ratio		3.90:1	
Tire Size/Type/Make/Model		11 x 22.5 Michelin	
Tire Pressure (Cold)		100	psi (kPa)
5th Wheel Setting (express in (mm) the distance 5th wheel fulcrum is ahead or behind the center line of bogie)		6" (152 mm)	in (mm)

PLEASE PRINT

MOTORWAYS

TRIP FUEL CONSUMPTION RECORD

TRIP # _____ DATE: _____ DRIVER: _____

TYPE OF TRAILER RIG (CHECK:)

TRUCK UNIT #: _____

_____ Long Box _____ Rocky Mountain

_____ Double _____ Flat Deck

_____ Triple

FROM (city): _____ TO (city): _____

RESET FUEL METER TOTALIZER TO ZERO AT START OF EACH TRIP

ODOMETER READING AT START OF TRIP _____ KM

TRIP START TIME _____

LOADED WEIGHT _____ KG or LB

ODOMETER READING AT END OF TRIP _____ KM

FUEL METER READING AT END OF TRIP _____ GAL

TRIP END TIME _____

APPROVED BY (DISPATCHER): _____

REMARKS: _____

_____

_____

GARDEWINE NORTH

DAILY FUEL CONSUMPTION RECORD

TRIP # _____ DATE: _____ DRIVER: _____

TRUCK # _____ TRAILER TYPE: _____

ODOMETER READING END: _____ ORIGIN: _____

ODOMETER READING START: _____ DESTINATION: _____

TOTAL MILES: _____ FUEL USED: _____

APPROVED BY DISPATCHER: _____

DRIVERS REMARKS: _____

_____

DRIVER INSTRUCTIONS: 1. Drivers are to record odometer readings and fuel readings accurately.
2. Drivers are to refuel their vehicles at the end of each trip and record where specified.

GARDEWINE NORTH

DAILY FUEL CONSUMPTION RECORD

TRIP # _____ DATE: _____ DRIVER: _____

TRUCK # _____ TRAILER TYPE: _____

ODOMETER READING END: _____ ORIGIN: _____

ODOMETER READING START: _____ DESTINATION: _____

TOTAL MILES: _____ FUEL USED: _____

APPROVED BY DISPATCHER: _____

DRIVERS REMARKS: _____

_____

DRIVER INSTRUCTIONS: 1. Drivers are to record odometer readings and fuel readings accurately.
2. Drivers are to refuel their vehicles at the end of each trip and record where specified.

GARDEWINE NORTH

DAILY FUEL CONSUMPTION RECORD

TRIP # _____ DATE: _____ DRIVER: _____

TRUCK # _____ TRAILER TYPE: _____

ODOMETER READING END: _____ ORIGIN: _____

ODOMETER READING START: _____ DESTINATION: _____

TOTAL MILES: _____ FUEL USED: _____

APPROVED BY DISPATCHER: _____

DRIVERS REMARKS: _____

_____

DRIVER INSTRUCTIONS: 1. Drivers are to record odometer readings and fuel readings accurately.
2. Drivers are to refuel their vehicles at the end of each trip and record where specified.

GARDEWINE NORTH

DAILY FUEL CONSUMPTION RECORD

TRIP # _____ DATE: _____ DRIVER: _____

TRUCK # _____ TRAILER TYPE: _____

ODOMETER READING END: _____ ORIGIN: _____

ODOMETER READING START: _____ DESTINATION: _____

TOTAL MILES: _____ FUEL USED: _____

APPROVED BY DISPATCHER: _____

DRIVERS REMARKS: _____

_____

DRIVER INSTRUCTIONS: 1. Drivers are to record odometer readings and fuel readings accurately.
2. Drivers are to refuel their vehicles at the end of each trip and record where specified.

APPENDIX F

THE FUEL CONSUMPTION REDUCTION POTENTIAL OF ANTI-IDLING DEVICES

F. THE FUEL CONSUMPTION REDUCTION POTENTIAL OF ANTI-IDLING DEVICES

F.1 Introduction

As mentioned in Section 1 of this report, an original objective of this project was to demonstrate the benefits and fuel consumption potential of anti-idling devices. Meaningful tests of these devices are best conducted in winter when urban pick-up and delivery drivers are most likely to leave their vehicles idling. For various reasons, it was not possible to secure the participation of trucking companies to conduct these tests within the time frame available for the project. Nevertheless, anti-idling devices appear to offer fuel saving benefits. The purpose of this appendix therefore is to present the research that was undertaken and suggested procedures for trucking companies who may wish to conduct their own tests.

F.2 Background on Anti-Idling Devices

Idling a diesel engine or gasoline engine can be costly in terms of fuel consumption. The average diesel engine at idle uses 2.5 l/h and a gasoline engine consumes 3.5 l/h. Pick-up and delivery trucks burn a significant amount of their fuel by idling, often unnecessarily, during deliveries and coffee breaks. Line haul trucks waste fuel by prolonged morning warm-ups or idling at truck stops, both of which can be easily eliminated.

Prospective participants in this demonstration were asked to express their views concerning the potential fuel saving impact of anti-idling devices on different types of operations. All were of the opinion that fuel savings to be achieved by preventing idling by long-haul drivers would be more efficiently and economically achieved through driver training and education. Further, carriers who equip their vehicles with tachographs can use the cards to identify the incidence of idling on long hauls. Excessive idling by long haul drivers therefore can be easily detected and corrected.

Urban P & D vehicles are not generally equipped with tachographs and, in the view of surveyed carriers, represent a major opportunity for reducing fuel consumed due to idling. In consideration of these observations and in view of the desirability of limiting the demonstration project's scope to only practical applications, the determination of the energy conservation potential of anti-idling devices in this experiment was to have been restricted to urban P & D operations.

There are a number of devices on the market which are designed to simplify the task of reducing idling time. For the independent owner/lease operator, a driver-actuated three minute delayed engine shutdown timer allows the operator to leave the vehicle running unattended for a three minute cool-down period. Other types of devices oriented toward long haul operations - in particular, relative to winter conditions - are actuated by engine temperature; the vehicle will keep running even though the vehicle is stopped and the key is removed, until the engine cools down to a preset level. Variations on this type of device will restart the engine when a preset minimum temperature level is reached.

A number of truckers are of the view that the electronic automatic restart feature is unnecessary and in some respects (e.g. battery drain) undesirable for urban P & D operations. At the same time, a device activated by the driver is not considered to yield significant fuel savings because its use is discretionary. The most useful and practical anti-idling device to test is considered to be one which shuts the engine off automatically after a preset period of time, regardless of whether the key is left in or removed. Such a device is perceived as having the advantage of allowing the engine to cool down gradually and then eliminating unnecessary idling following the cool down period.

To date, fleet operators have been slow to introduce equipment aimed at reducing idling due to concern about costs, reliability, and driver acceptance among other things. The aim of this demonstration project was to have been to attempt to break down this reluctance and show the value of anti-idling devices for truckers conducting P & D functions.

F.3 The Kysor Idlestop

Following an evaluation of the various types of anti-idling devices available, it was concluded that the device manufactured by Kysor/ Cadillac most closely suited the requirements of trucking companies. Kysor claims that their product can save as much as four percent of total consumption, although savings as high as 25% have been reported (Motor Truck, October, 1980).

The Kysor Idlestop is designed to allow the engine to idle for five minutes and then will shut down the engine automatically. A time cycle override allows emergency shutdown without the five minute idle period. Three variations of the device are available. The "Key Off" option allows the driver to turn off the ignition, pocket the keys, and leave the engine idling for five minutes before it shuts down. Under the second option, "Key On", if the driver leaves the vehicle with the key on and the engine idling, this option will monitor the tractor parking brake's being set and will shut down the engine five minutes after the signal is received. A relay that disables the starter and accessories to prevent battery drain are available. The third alternative, "Idlestop-Combination", combines the features of the "Key-Off" and the "Key-On" systems. That is, the engine will idle for five minutes whether the key is turned on or off. The "Idlestop-Combination" equipped with the starter/accessory disabling relay was the selected device which would have been tested in this demonstration project had time and other circumstances allowed.

F.4 Other Devices for Reducing Idling

Other anti-idling devices were examined for their possible inclusion in the tests but were not selected because they did not fit the requirements of the experiment:

a) Sureco Stop-Rite: This device is similar to the Kysor Idlestop, however, the unit can be overridden by the driver by simply

flipping a toggle switch to the "off" position, disengaging the unit. This device was rejected because there is too much dependence on driver discretion for successful testing.

b) Ruhl Idle Time Control: This device is a very sophisticated unit which will shut down the engine after five minutes of idling in a neutral/park position. The device has a 30 second warning buzzer advising the driver that the engine is about to disengage. The problem with this built-in feature is that many vehicles being used today have air-brake systems and it requires an air-brake unit more than 30 seconds to build up pressure to release the brake and begin motion. This system would probably frustrate the driver to a point where the temptation to tamper with the device would be great.

c) Ruhl Thermostart: This device is activated by monitoring engine temperature and will shut down the engine once a certain idling temperature is set. It has an added feature of starting the engine at a preset temperature setting. This device is very useful for reducing idling in long haul situations but is not quite relevant for local pick-up and delivery operations.

d) DAP Thermostart: This device operates in similar fashion to the Ruhl Thermostart except that it will make three further start attempts if it fails to start on the first attempt. This type of device, if improperly installed or in cases of electrical malfunction, could result in starter and battery damage.

e) Preco E1T-5: This device is similar to the Kysor but has a driver activated override switch.

Although no tests were conducted within the scope of this demonstration, one Winnipeg firm (Associated Beer Distributors) has achieved significant fuel savings as a result of their implementation of the Kysor Idle-Stop on their urban P & D fleet.

F.5 Suggested Testing Procedures

In order to test fuel savings achievable through the installation of anti-idling devices, a fleet manager may use the following test procedure.

1. Select at random two trucks specified as identically as possible (eg. age, power unit, tires, transmission, mileage, routes operated, etc.) which are representative of the urban pick-up and delivery fleet.

2. Obtain a fuel economy data base for each of the two trucks by recording the fuel consumed and miles/kilometres (and/or hours) travelled every day for 20 days.

3. Collect daily fuel consumption records keeping the following principles in mind:

   a) Power units and trailers/bodies should not be used for other purposes (eg. long haul highway operation) or other routes nor should they be modified in any way while the tests are being conducted;

   b) Vehicles should be assigned to routes which provide enough distance and time coverage to consume a minimum of 30% of the tank capacity or a minimum of 6 gallons (27 litres) of fuel per day, whichever is greater;

   c) To the extent controllable, vehicles should be operated according to vehicle, engine, and transmission manufacturers' recommendations (eg. engine speed and shift points);

   d) Both vehicles should be in proper operating condition at all times, in similar mechanical condition representative of the condition of all vehicles in the fleet, and undergo regular

maintenance whenever necessary at approximately the same time for all test and non-test vehicles operating in similar circumstances; and,

e) Select drivers sufficiently skilled so that the test results will not be affected by improvement in drivers' technique during the test period.

4. Fill the vehicle's fuel tank to capacity every morning and record the amount of fuel taken and the odometer reading. If possible, appoint a single individual gas "jockey" to pump the fuel and, where deemed necessary, equip the vehicle tanks with gas cap locks.

5. After fuel consumption and miles per gallon (or litres per 100 kilometres) have been recorded for 20 working P & D days, have the anti-idling device determined to be most suitable installed by a competent reliable supplier on each of the two trucks.

6. Following installation, record fuel consumption and miles (kilometers) for another 20 working P & D days.

7. After the "test" runs (i.e., with device) have been run, determine the average fuel consumption for each truck before and after the device was installed and compare.

8. The statistical significance of the difference may be determined by using procedures outlined in any elementary statistics textbook or in the documents listed in Appendix D.

It is important to note that the two month period in which the tests are run should be as similar as possible in terms of weather conditions. In order to run the "base" (i.e., without device) cycles and "test" (i.e., with device) cycles back-to-back, make sure your local supplier has anti-idling devices in stock and that he will be ready to install them immediately following the completion of the "base" cycles.

APPENDIX G

SELECTED BIBLIOGRAPHY ON ENERGY CONSUMPTION TEST PROCEDURES

Certain documents published by the Society of Automotive Engineers could be helpful to truck fleet managers wishing to conduct their own tests:

1. John F. Weiss, Claude M. Ligon, Claude Travis and Henry Seiff, "An Analysis of Commercial Vehicle Speed Control Concepts", SAE Technical Paper Series #821258, 1982.

2. Terry Blevins and John Stephan, "Truck Electronic Engine Controls", SAE Technical Paper Series #820907, 1982.

3. "Joint TMC/SAE Fuel Consumption Test Procedure - Type II", SAE J1321, October, 1981.

4. "Joint RCCC/SAE Fuel Consumption Test Procedure (Short Term-In-Service Vehicle) - Type I" - SAE J1264, April, 1979.

5. "Fuel Economy Measurement - Road Test Procedure", SAE J1082b, January, 1979.

These can be obtained by writing to:

Society of Automotive Engineers
400 Commonwealth Drive
Warrendale, Pennsylvania
15096

A practical document for fleet managers wishing to conduct their own tests is available from:

National Technical Information Service
U.S. Department of Commerce
Springfield, Virginia
22161

6. U.S. Department of Energy, Assistant Secretary for Conservation and Solar Application Programs, "A Fleet Manager's Guide to Testing Vehicles for Valid Results", 1981.

Another useful article available from university libraries is:

7. J.H. Kent and N.R. Mudford, "Motor Vehicle Emissions and Fuel Consumption Modelling" in Transportation Research, Vol. 13A, pp. 395-406, Pergamon Press Ltd., Great Britain, March 1979.